Marketing Research Report No. 881

ALFALFA DEHYDRATION, SEPARATION, and STORAGE:

Costs and Capital Requirements

U.S. Department of Agriculture • Economic Research Service

ABSTRACT

Cost per ton for separating chopped alfalfa into high protein and high fiber fractions ranged from $3.24 in the smallest model producing 4,950 tons per year to $0.30 in the largest producing 17,325 tons per year. Operating costs were synthesized using the economic-engineering approach to determine the economic feasibility of the USDA-developed separating technique. Cost for three alternative separation flows in six models of different capacities were analyzed. Investment per plant increased between $64,000 to $81,500 for additional equipment and storage facilities. The total cost of dehydration and separation was the greatest in the smaller models, $21.61 per ton. The largest model had the lowest cost, $11.31 per ton. Assuming 60 percent of each models output was stored, average per ton cost increased to $26.22 in the smaller and to $14.72 in the larger model.

Key Words: Alfalfa, Processing, Dehydration, Storage, Economic-engineering, and Mixed feeds.

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PREFACE

This study is part of the Department's broad program of economic research directed toward expanding market outlets and increasing efficiency in marketing farm products. The farmer has a double interest in the dehydrated alfalfa industry's efficiency, since he produces the alfalfa and also purchases the finished product.

Recent research jointly sponsored by the Western Utilization Research and Development Division of USDA's Agricultural Research Service in Albany, Calif., and the Nebraska Department of Economic Development has produced a technique for separation of the fiber and protein in dehydrated alfalfa. George Kohler, ARS, and Joseph Chrisman, of the Nebraska Department, developed the separation technique and provided much assistance in developing this study. ARS requested that the Economic Research Service make an economic evaluation of this technique. The results of the study comprise this report.

The author acknowledges the aid of individuals (and their companies) who cooperated in the ERS research program. No report of this type would be possible without the basic information supplied by alfalfa dehydrators in Kansas and Nebraska. Equipment companies and their engineers made available their experience, with advice on cost information for equipment and facilities. The report is based on these costs.

Washington, D.C. 20250 May 1970

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SUMMARY

Separating alfalfa leaf and stem into high-protein feed for hogs and poultry and high-fiber feeds for cattle appears economically feasible. Having more nutrients available per ton and extending the alfalfa cutting season should offset the slight added cost of separation--$0.30 to $3.24, depending on scale of operations.

Costs of the new separation process were synthesized for six model dehydrating plants, using the economic-engineering technique. The standard models represent six evaporative drum capacities ranging from 10,000 to 33,000 pounds of water an hour.

Investment costs for the standard models--without separation--ranged from $190,200 for the smallest plant, producing 4,950 tons a year, to $321,400 for one producing 17,325 tons. Investment per ton of annual capacity ranged from $38.42 to $18.55. Annual operating costs dropped from $18.37 a ton for the smallest plant to $11.01 for the largest. Fixed costs varied in the same ratio from 33 to 24 percent of the total cost of production. As hourly output increased from 1½ to 5¼ tons, the total cost decreased 40 percent.

Equipment and facilities for separation increased model costs by $64,000 to $81,500. Three alternative systems for each of the six models allowed comparison of 18 operations, all sufficiently different to change equipment requirements and costs.

Dehydration and separation costs were highest in the smallest model--$21.61 a ton. The largest model cost least--$11.31 a ton. Separation added between $1.70 to $3.24 a ton over the standard model costs in the smallest group. In the largest volume group, separation increased the cost between $0.30 to $1.03 a ton.

Because dehydrated alfalfa is unstable under ordinary storage conditions, alfalfa dehydrators increasingly use inert gas storage to preserve product quality. Storage costs, including those for inert gas, for standard models ranged from $7.49 a ton in the smallest model to $5.40 in the largest. Models separating alfalfa had slightly higher costs for additional storage facilities and conveying equipment--$7.69 for the smallest and $5.69 for the largest.

Combining all costs allowed calculation of the total cost per ton. The most efficient separation model increased the total cost per ton between $1.81 to $0.47 over the standard model costs of $22.87 and $14.25. The highest cost separation model increased the per ton cost between $3.35 and $1.20.

ALFALFA DEHYDRATION, SEPARATION, AND STORAGE: COSTS AND CAPITAL REQUIREMENTS

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INTRODUCTION

Commercial dehydration of alfalfa began about 1930. The practice offset weather hazard to some extent by reducing dependence on field-drying and avoiding nutrient losses. The dehydrated alfalfa of the thirties was an improvement over the average sun-cured meal, but it was quite inferior to the products marketed today.

The war years (or the decade of the forties) gave the alfalfa dehydrating industry its greatest boost. During this period, production increased fourfold to slightly less than a million tons annually, but quality increased only slightly.

During the fifties, the industry, with the cooperation of agricultural experiment stations and USDA, made a great effort to lower dehydration costs while producing superior products, so that the use of dehydrated alfalfa was expected to continue to grow. The many improvements introduced during this decade included the adoption of automated tube firing of the dehydrator, which increased productive capacity. Additional improvements came through the use of automatic feeders, self-propelled field choppers, inert gas storage, pelleting, chemical antioxidant, and bulk handling. All of these innovations combined to give better quality products that can be more easily handled.

During the same period, new information was acquired on the specific nutritional needs of various types of animals. Today's dehydrated alfalfa, even though greatly improved over the earlier product, is evidently not a completely satisfactory feed ingredient for universal use (1). 1/ Monogastric animals, such as poultry and swine, need feed that is low in fiber, yet high in protein and energy. Ruminant animals, on the other hand, can make good use of fibers and can utilize nonprotein nitrogen. Urea is rapidly being substituted for vegetable protein in ruminant feeds because of its lower cost.

Leaders of the industry have long recognized the need for new products to meet the requirements of specific types of animals. The leaves of the alfalfa plant contain most of the protein, while fiber is concentrated in the stems. Numerous tests and experiments have been conducted to efficiently separate these into individual products.

1/ Underscored numbers in parentheses refer to items in the References, p. 43.

The USDA Western Utilization Research and Development Division of Agricultural Research Service and the Nebraska Department of Economic Development have achieved a breakthrough in developing a new airstream method of separating leaves from stems. This technique has been field tested for two harvest seasons to determine the efficiency of the system. Tests have shown favorable results in product separation (2), (3), (4), (5), (6), (7), (8).

The economic aspects of separation and the market potential for these new products must be determined to aid the dehydrating industry in making a wise decision on the acceptance of this technique and the installation of new equipment. This study is concerned with the economic feasibility of producing these products. Added costs for separation must not place these products beyond the economic reach of feed manufacturers and livestock feeders. To be accepted, the product must be competitively priced and generally available throughout the year.

Future economic research will relate to an economic evaluation of the products and potential markets. In this phase, market demands will be derived for each of the major U.S. feeding areas. Estimates will be made for major livestock categories and total estimates compiled for the major areas. All costs (including transportation costs) will be considered to determine the role of the new products in feed formulation and in general, the overall marketing of feeding ingredients.

METHODOLOGY

In this study, the costs of dehydrating, separating, and storing alfalfa include plant and equipment costs as well as operating costs for each of these major functions. Cost data are sufficient to make an economic evaluation of total plant operations. However, the study does not consider individual operation decisions, such as optimum plant location analysis, which would involve an examination of alfalfa purchasing and distribution patterns, transfer costs, or the position of competing products.

The cost analyses were developed by systematically analyzing each of the major functions. Dehydration costs are developed first. Separation costs are synthesized from these costs by three alternative methods. Finally, storage costs are derived from the storage requirements of plants that do not separate dehydrated alfalfa and those that do. Each major function is discussed in detail as follows:

Alfalfa dehydration involves a number of basic processes which will be used in comparison of costs. Therefore, the economic-engineering approach was used to construct different-size alfalfa dehydrator operations, each of which would incorporate the basic processes. This study examines plant operations for six volumes to illustrate the relationships and costs which characterize plant operations at various levels of production. This approach required determining various physical input-output relationships for each process in the total manufacturing process. Standardized costs were applied to physical input requirements to derive cost functions for the model plants.

These basic model plants were constructed to provide guidelines for equipment and facility costs and other costs incurred in alfalfa dehydration, air

separation, and storage. Basic input and output data for these models were obtained from interviews with selected dehydrator operators in Nebraska and Kansas. Other pertinent information on equipment costs, utility rates, and wage rates necessary to complete the analysis was obtained from both industry and Government sources. Investment and operating costs for these models represent average costs for the Nebraska and Kansas area. Costs may vary for plants in particular areas of each State, depending upon representative costs for the locality.

BASIC PLANT OPERATIONS

A description of individual segments of the complete alfalfa dehydrating process follows. Figure 1 illustrates the physical flow of the alfalfa through the plant.

Receiving.--The raw material or chopped alfalfa is trucked to the plant, where it is dumped on a hydraulic lift platform which, when elevated, tumbles the material onto the slat conveyor of the automatic feeder. The lift, sufficiently large to allow adequate storage space, makes it unnecessary for trucks to wait to unload. The material is conveyed up the ramp of the feeder, where it is leveled and evenly fed into a screw conveyor, which augers the material into the drum. A variable control on the automatic feeder adjusts its rate of feed to suit the size and moisture content of the material being dehydrated.

Dehydration.--Two general types of rotary drum dryers are the single-pass and the triple-pass. The single-pass dryer uses a single rotating drum. Flights running the length of the walls of the drum are arranged to pick up the alfalfa and spread it evenly over the entire cross-sectional area of the drum as it is rotated. A single baffle is oriented to increase air velocity during dehydration. The material is rapidly moved away from the direct flame of the furnace at the front of the drum. The leaves dry almost instantly and are quickly removed from the dryer to the exhaust fan. The heavier stem material requires a longer evaporation time. The heavier material is tumbled to the discharge end of the drum and then moved to the hammermill by the pneumatic system.

A triple-pass drum consists of three concentric cylinders. These cylinders are interlocked mechanically, and all rotate at the same speed. The inner cylinder has the highest temperature, with progressively lower temperature and air velocity in the intermediate and outer cylinder. The air stream created by the exhaust fan draws the material through the inner cylinder, back through the intermediate cylinder, and forward through the outer cylinder to the discharge end of the drum. The alfalfa is carried to the top of each cylinder by built-in flights.

As in a single pass, the leaves dry quickly and move toward the discharge. The heavier stem material takes longer to dry and moves more slowly through the three passes. The capacity of a given drum in terms of dehydrated output depends primarily on the moisture content of the chopped alfalfa. Drums are rated in terms of water evaporative capacity per hour. Alfalfa usually passes through the drum in 3 to 5 minutes.

The alfalfa may be removed by either a positive or a negative pneumatic system. With a positive air system, the exhaust fan provides the air for

Code

1. Hydraulic dump
2. Forage feeder
3. Rotary drum
4. Pneumatic system
5. Hammermill
6. Pneumatic system
7. Pellet mill
8. Boiler
9. Cooler
10. Scalper
11. Scale
12. Shipping
13. Storage (short-time)
14. Storage (inert gas)

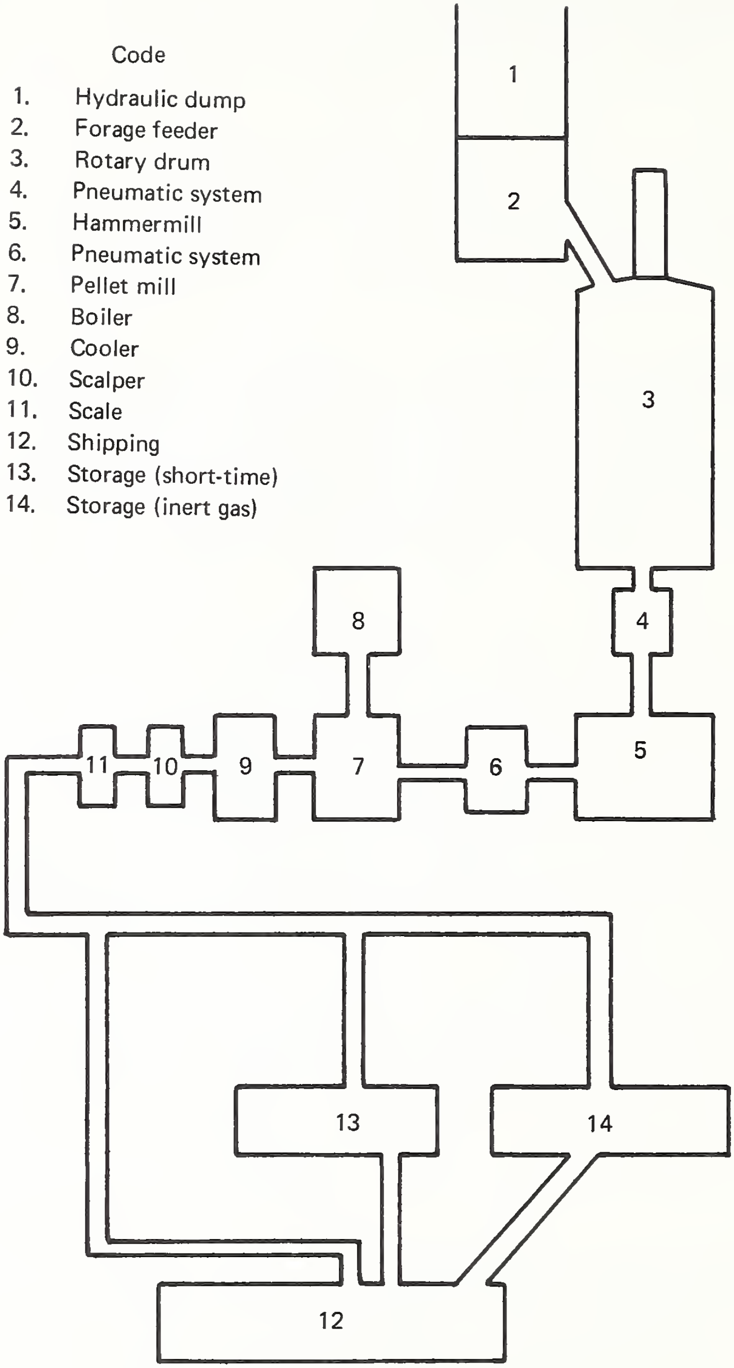

Figure 1. — Functional process flow diagram.

combustion and drying and generates the airstream which moves the alfalfa through the exhaust fan into a collector where it separates from the hot moist gases. The dry alfalfa then passes through a cooling fan into a cooling collector, and from there to the hammermill.

Alternatively, a negative air system may provide air for combustion and air flow to move the product through the drum. The dehydrated material does not pass through the fan in this system. The material is pulled from the drum to a collector where the dried material settles out. Negative pressure removes the hot gases and moistened air from the collector. The dehydrated product then flows through an airlock into the hammermill.

Grinding.--A hammermill further reduces the dehydrated alfalfa to a uniform particle size. Screens may be changed in the hammermill to provide the fineness of grind desired.

A negative pneumatic system takes the alfalfa from the hammermill and elevates it to the overhead bins. From these bins it is gravity fed into a bagger or a pellet mill, or is loaded out in bulk.

Pelleting.--Dehydrated meal is fed by gravity into the conditioning chamber where steam is added to facilitate the pelleting operation. Moisture condensed from the steam serves as a lubricant to assist the meal in passing through the die. The hot pellets are then elevated and flow by gravity through a cooler. The temperature is reduced and excess moisture removed from the pellets. Pellets are then loaded for direct shipment or placed in short- or long-term bulk storage facilities.

Storage.--Storage in this case involves long-term storage where inert gas is used. Preservation of quality by preventing losses of vitamins and other nutrients is achieved when the storage tanks are blanketed with inert gas. Dehydrated alfalfa pellets are stored for about 6 months, and tanks are emptied around the beginning of the new harvest season. As orders are received, the bulk pellets are taken from the storage tanks and loaded into trucks or railcars.

MODEL DEHYDRATING PLANTS

Six model plants analyzed in this study were developed for dehydrating systems at six levels of designed capacity based on current mill engineering designs. Costs of operating each size model are estimated. Production volume of each model plant is determined by the water evaporative capacity per hour for each plant.

Model plant volume sizes are based on the average evaporative capacity of the drum per hour. Six tonnage volume sizes are used: 1 1/2, 1 3/4, 2 3/4, 3 1/2, 4 1/2, and 5 1/4 tons of dehydrated alfalfa per hour (table 1). Annual output for these models is estimated to be the daily 22-hour output for 150 working days. Plant operations are further analyzed for three systems of air separation milling. In effect, they are different operations and may be considered as 18 separate alfalfa dehydrating plants. Each has its own set of requirements for equipment and facilities; cost estimates would be based on these requirements.

Table 1.--Specifications of models

Model	Evaporating capacity per hour	Drum	Rated capacity per hour	Hourly production	Annual production
	Pounds	Type	Tons	Tons	Tons
A..........	10,000	Single-pass	1 to 2.5	1 1/2	4,950
B..........	12,000	Triple-pass	1 to 2.5	1 3/4	5,775
C..........	18,000	Single-pass	2 to 4	2 3/4	9,075
D..........	22,000	Triple-pass	2 to 4	3 1/2	11,550
E..........	30,000	Single-pass	4 to 6	4 1/2	14,850
F..........	33,000	Triple-pass	4 to 6	5 1/4	17,325

The six volume size plants are designated by letter (A, B, C, etc.) throughout the report. For example, a particular size and method of separation is referred to throughout the report as model AI, BIII, CII, etc.

Specifications for Model Plants

The basic specifications common to all models are described below. With this established, operational standards and costs may be calculated and costs compared.

Type of operation.--The plants are assumed to be operating two 12-hour shifts a day, including 1 hour's slack time in each shift. Evaporative capacity per hour as indicated in table 1 determines output of the plants. The rated capacity varies considerably from the actual output of equipment. The moisture content of the alfalfa chop and the evaporative capacity of the drying drum determine the amount of raw material which can be dehydrated in a given time. For a drum of a given evaporative capacity, the amount of raw alfalfa processed or the quantity of dehydrated alfalfa produced is inversely related to the moisture content. Moisture content of the alfalfa chop will range between 70 and 85 percent moisture. Dehydrated alfalfa will have a moisture content of 8 to 10 percent. In estimating output of the models, moisture in alfalfa chop is assumed to be 75 percent, which is reduced to 8 percent in the finished product.

Another important cost consideration is downtime, or unproductive time, that occurs because of poor weather, mechanical breakdown, lack of coordination between field cutting and plant requirements, and lack of hay. It is most important that these be minimized; however, plant interruptions do occur.

Equipment.--The kind, type, size, and number of equipment items required for each model are synthesized from input-output relationships and manufacturer's

equipment specifications. Each model has the dehydrating and processing equipment potential to produce a greater capacity than is assumed. Increased capacity would depend on factors being more favorable or even ideal.

Equipment is divided into six categories; four of them are concerned with the primary manufacturing operation, plus a miscellaneous category that includes equipment used in a number of operations. A fifth category, loading out, involves transfer of material from temporary storage to railcars or trucks. The equipment cost represents an average delivered price of the equipment ready for installation. The equipment installation costs for each model are estimated as separate cost items.

Receiving equipment includes the truck platform hydraulic dump, automatic forage feeder, and conveying equipment for handling chopped alfalfa from receiving point to the dehydrator. Dehydrating equipment includes the rotary drum (single- or triple-pass), tube burner, and the pneumatic conveying system for moving the dehydrated product to the grinder. Grinding equipment includes the hammermill and the pneumatic system for conveying the ground meal to the working bins over the pellet mill. Pelleting equipment includes the pellet mill, cooler, scalper, conveying equipment, and boiler. Miscellaneous equipment includes items not assignable to a specific operation, principally the air compressor.

Facilities.--Variables that will affect construction costs include: type and size of buildings constructed, building materials used, and local building codes. All models are assumed to be on level sites with access to both a railroad and a highway. Soil conditions are assumed to be satisfactory for the building and storage facilities required. Buildings are constructed of a combination of masonry and steel sheeting, and were designed to allow future expansion.

The mill building houses the pelleting equipment and work bins. A concrete block boilerroom building is attached. Both buildings have reinforced concrete roofs with structural beam supports. The mill building and the boilerroom have concrete floors and foundations. The masonry building for the shop and office are concrete-floored, on reinforced concrete foundations. Bolted steel tanks comprise temporary storage for the loadout operation. These tanks are mounted on structural steel tank framework set into a concrete foundation. Each tank utilizes a long tube-type conveyor for loading both railcars and trucks with equal efficiency. A rail siding is provided with each model. Empty cars are spotted on the track and are moved from the loadout area as they are loaded.

Acreage requirements for the model plants are based on amount of land occupied by buildings and storage tanks plus adequate space for truck movements around the yard. Models were assumed to require a minimum of 4 acres, at an assigned cost of $2,000 per acre or $8,000 total land cost. This, of course, could vary greatly with the site.

Labor.--In the models, labor is classed as production or maintenance. This study assumes that a worker's time may be divided between production and maintenance work in any proportion during his 12 hours of work.

Production labor handles all operations from receiving through pelleting. An average hourly wage of $2 is allowed for production workers. To best use

labor, new plants are usually designed for easy access to all controls and all equipment. In established dehydrating plants, inefficient operations are often the result of poorly planned expansion programs.

Maintenance labor includes daily maintenance and repair jobs as well as preventive maintenance around the plant. The hourly maintenance wage is assumed to be $2.30 per hour.

Depreciation.--Rates for estimating depreciation costs for the models are developed from information provided by alfalfa dehydrators and equipment manufacturers, and Internal Revenue Service guide (9).

Obsolescence appears to be a primary consideration in the establishment of depreciation rates. Although some firms in the industry take a longer or shorter depreciation period, a 15-year depreciation period for equipment is assumed to be average. Equipment for all model mills was depreciated by the straight-line method over a 15-year period.

Building depreciation extends over 25 years. Buildings are primarily of masonry construction and can have a longer depreciable period than equipment. (Many firms in the industry have less-permanent buildings and therefore estimate building depreciation over a 10- to 15-year period.) Storage bins are either bolted or welded steel, and depreciate over a 20-year period. A case can be made for allocating somewhat higher depreciation charges for plants since they do operate 24 hours a day. However, annual hours of operation were not considered to be of major importance in making cost estimates for the models.

Interest.--Annual interest cost is estimated by multiplying 3 1/2 percent, or half the nominal interest rate of 7 percent, by the total capital investment in equipment and facilities. In addition, a rate of 7 percent is used on the nondepreciable land investment of $8,000.

Interest is an imputed cost which does not take into account the source of the invested capital. Although business firms show interest as an expense if paid to outside agencies, true capital cost includes an interest allowance on owner equity.

Taxes.--Property taxes vary considerably among States and even among communities within a State. In some States, taxes are levied on all property, while in others, equipment would be exempt. In addition, communities in most States establish the percentage of total value to be assessed. In this study, a tax rate of 1 1/2 percent on the initial investment is used in the models. Interviews of plant personnel gave a wide range of rates.

Insurance.--Factors affecting the cost of insurance for an alfalfa dehydrator plant include building materials, types of electric motors, type of fire prevention equipment in the plant, and the location of the facility with regard to local fire protection. The last item is very important in rate determination. This study indicated that a rate of $1 per $100 investment in buildings and equipment is used to estimate the average cost of insurance.

Utilities.--Utilities include electricity, water, and natural gas. Electricity requirements are estimated for the average machine time required in the

alfalfa dehydrating process with normal power use by equipment. An average rate of 1.5 cents per kilowatt hour is used. The straight-line method is used, since previous studies have shown the total electric cost increases in direct proportion to increases in feed tonnage output.

Water consumption is estimated at 100 gallons per day for each employee's personal use and 4.5 gallons for each boiler horsepower-hour. An average cost rate for water purchased was assumed at 20 cents per 1,000 gallons, which includes the higher cost for the initial charge or minimum quantity used.

Natural gas is used for the boiler, the dehydrating drum, and the inert gas generator. Natural gas rates, like electricity rates, vary considerably between locations. Since the dehydrator is a large consumer of natural gas, the lowest possible rate is usually secured. An average rate of 31 cents per 1,000 cubic feet applies to all models.

Maintenance and Repair.--Annual cost for maintenance and repairs for dehydrating equipment and facilities is estimated to equal 7 percent of the initial investment. This facility maintenance cost is usually quite small, compared with that of equipment repairs. The cost of equipment repairs and parts is included in the total cost, as is the cost of repair services hired by the mill.

Administrative Costs.--These costs include the portion of general office costs allocated to the alfalfa dehydration process. Included is part of the manager's salary, office workers' wages, and miscellaneous office expenses. In the two smaller models, a $3,000 annual cost was assumed; the two medium size models, $3,500; and the larger models, $4,000 a year.

Supervisor's Salary.--The assumed salary was based on information received from dehydrator plants. These costs may be high, but it is most important to have a competent supervisor. Costs range from $4,000 for the small model to $5,000 for the larger models. This cost has been prorated as the portion of the supervisor's time spent in overseeing the operations of the plant.

Investment in Equipment and Facilities

Total plant investment for equipment and facilities ranged from $182,200 for Model A to $313,400 for Model F (table 2). Land costs would increase total cost for the smaller model to $190,200 and the larger one to $321,400.

Investment per ton of annual capacity ranges from $38.42 a ton for the smaller Model A to $18.55 a ton for the larger Model F. Significant reductions could be realized with a slight increase in hourly production or a longer harvest season.

The equipment and facilities costs shown in table 2 were synthesized from input-output relationships developed through interviews with dehydrators and from recommendations made by equipment manufacturers. A detailed breakdown of equipment and facility costs for all operations for the six models is in appendix A.

Table 2.--Equipment and facility costs: All models

Cost items	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Equipment:						
Receiving........	13,900	14,300	13,900	14,300	14,300	14,700
Dehydrating......	36,500	48,300	44,900	59,500	59,000	90,000
Grinding.........	9,800	9,800	11,500	11,500	12,100	12,100
Pelleting........	34,100	34,100	40,800	40,800	46,900	46,900
Loading out......	4,000	4,000	5,800	5,800	7,500	7,500
Miscellaneous....	2,500	2,500	3,500	3,500	4,000	4,000
Total..........	100,800	113,000	120,400	135,400	143,800	175,200
Installation of equipment 1/......	30,200	33,900	36,100	41,000	43,200	52,400
Facilities:						
Mill building and boilerroom..	17,700	17,700	22,300	22,300	26,000	26,000
Office and shop..	9,600	9,600	14,500	14,500	18,900	18,900
Loading out tanks...........	23,900	23,900	32,400	32,400	40,900	40,900
Total..........	51,200	51,200	69,200	69,200	85,800	85,800
Grand total..	182,200	198,100	225,700	245,600	272,800	313,400

1/ Estimated at 30 percent. Includes mechanical, electrical, and plumbing costs.

Installation costs are estimated separately (table 2). Total cost of equipment varies between 69 and 74 percent of the total investment. Equipment and installation costs per unit of output tend to be slightly greater in the smaller models. Cost in the larger capacity equipment does not increase directly with the increased capacity.

There are several major differences in costs between the smaller and larger models. Increased size of equipment, such as the drum and pelleting equipment, account for major cost differences in equipment. In facility costs, the differences occur with increased space requirements.

Building costs primarily depend on the space required on variations made in the operation and on increased output. Major buildings are the mill building, boilerroom, and office and shop. The models also include a minimum amount of short-term storage in the loadout tanks. Representative construction costs are used for each type of building and for storage tanks.

Total costs for all facilities range from $51,200 for Model A to $85,800 for Model F. Facilities costs would average about 20 percent less if steel construction were used instead of masonry. However, this relationship would vary with facility size, storage capacity, and competitive conditions in the two types of construction.

Facility costs account for between 26 and 31 percent of the total cost of equipment and facilities.

Operating Costs

Operating costs are basically costs incurred in alfalfa dehydration. These costs do not include the cost of the hay, cutting, trucking, storage, or marketing. These items would be considered in a total cost study or a plant location analysis.

Operating cost for the models is shown in table 3. Costs were categorized as either fixed or variable and are discussed in the order that they appear in the tables.

Fixed

Ownership costs account for the major portion of fixed costs. The initial investment in equipment and facilities is spread over the productive life of the operating unit. Depreciation is a prime example of this cost. Other fixed costs include administrative, salaries, taxes, insurance, and interest on investment. In the short run, these costs are fixed and do not vary with the output.

Depreciation.--Depreciation for the models ranges from $1.10 to $2.23 a ton (table 4). Operations E and F have the lowest cost and Model A the highest. Equipment depreciation ranges from 84 cents to $1.77 a ton; Model A has the highest cost and Model E the lowest. Equipment depreciation comprises 76 to 80 percent of the total cost of depreciation. Facility depreciation decreases about 50 percent between the highest and the lowest cost models.

Taxes.--Taxes for the six models ranged from 28 to 58 cents a ton. The assumed rate of $1 per $100 investment was used. Taxes for Model F were about 48 percent of those in Model A.

Insurance.--An insurance rate of $1 per $100 investment in buildings and equipment was used to estimate the annual cost of insurance. The cost in these models ranges from 18 to 37 cents a ton; smaller plants have higher costs.

Interest.--Interest on investment is a major fixed cost in each model. It ranges from 67 cents a ton for Model F to $1.41 a ton for Model A. Interest accounts for about 20 percent of the total fixed cost for all models. Interest in Models E and F are less than 50 percent of Model A's interest.

Administrative costs.--Administrative duties that must be performed daily in the operation of a dehydrating plant include: general management, personnel

Table 3.--Operating costs: All models; no separation

Cost items	Model A		Model B		Model C		Model D		Model E		Model F	
	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton
	Dollars											
Fixed costs												
Administrative........	3,000	0.61	3,000	0.52	3,500	0.39	3,500	0.30	4,000	0.27	4,000	0.23
Salary (Supervisor)...	4,000	.81	4,000	.69	4,500	.50	4,500	.39	5,000	.34	5,000	.29
Depreciation 1/.......	11,030	2.23	12,080	2.09	13,530	1.49	14,850	1.29	16,350	1.10	19,030	1.10
Insurance 2/..........	1,830	.37	1,990	.34	2,260	.25	2,460	.21	2,740	.18	3,140	.18
Taxes 3/..............	2,860	.58	3,100	.54	3,510	.39	3,810	.33	4,230	.28	4,830	.28
Interest 4/...........	6,980	1.41	7,540	1.31	8,500	.94	9,200	.80	10,200	.69	11,600	.67
Total..............	29,700	6.01	31,710	5.49	35,800	3.96	38,320	3.32	42,520	2.86	47,600	2.75
Variable costs												
Labor 5/..............	17,590	3.55	17,590	3.04	24,720	2.72	29,340	2.54	34,730	2.34	34,730	2.00
Utilities:												
Natural gas 6/......	16,240	3.28	19,350	3.35	29,500	3.24	36,730	3.18	46,780	3.15	53,020	3.06
Electricity 7/......	11,960	2.41	13,150	2.28	15,340	1.69	17,900	1.55	20,900	1.41	24,340	1.40
Water...............	190	.04	210	.04	300	.03	340	.03	450	.03	520	.03
Maintenance and repairs 8/...........	12,750	2.58	13,870	2.40	15,800	1.74	17,190	1.49	19,140	1.29	21,940	1.27
Additive 9/...........	2,480	.50	2,890	.50	4,540	.50	5,780	.50	7,430	.50	8,670	.50
Total..............	61,210	12.36	67,060	11.61	90,200	9.92	107,280	9.29	129,430	8.72	143,220	8.26
Grand total.......	90,910	18.37	98,770	17.10	126,000	13.88	145,600	12.61	171,950	11.58	190,820	11.01

1/ Depreciation; straight line method: Equipment 15 years; bins and tanks, 20 years; building 25 years.
2/ Insurance: \$1 per \$100 initial investment.
3/ Taxes: 1½ per cent initial investment.
4/ Interest: 7 percent on ½ average investment, 7 percent on land value.
5/ Labor: Average for mill labor \$2, maintenance labor \$2.30. (Includes 30 cents for fringe benefits.)
6/ Natural gas: 31 cents per 1,000 cubic feet.
7/ Electricity: 1.5 cents per kilowatt hour.
8/ Maintenance and repairs: 7 percent of initial investment.
9/ Additive: Cost of antioxidant application estimated at 50 cents per ton.

Table 4.--Depreciation costs: All models

Item	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Equipment:						
Total cost	131,000	146,900	156,500	176,400	187,000	227,600
Annual depreciation	8,740	9,790	10,440	11,760	12,500	15,180
Depreciation per ton	1.77	1.69	1.15	1.02	.84	.88
Mill building and boilerroom:						
Total cost	17,700	17,700	22,300	22,300	26,000	26,000
Annual depreciation	710	710	890	890	1,040	1,040
Depreciation per ton	.14	.12	.10	.08	.07	.06
Office and shop						
Total cost	9,600	9,600	14,500	14,500	18,900	18,900
Annual depreciation	380	380	580	580	760	760
Depreciation per ton	.08	.07	.06	.05	.05	.04
Loading out tanks:						
Total cost	23,900	23,900	32,400	32,400	40,900	40,900
Annual depreciation	1,200	1,200	1,620	1,620	2,050	2,050
Depreciation per ton	24	.21	.18	.14	.14	.12
Total:						
Total cost	182,200	198,100	225,700	245,600	272,800	313,400
Annual depreciation	11,030	12,080	13,530	14,850	16,350	19,030
Depreciation per ton	2.23	2.09	1.49	1.29	1.10	1.10

activities, quality control, typing, and bookeeping. These costs will vary considerably, depending on organizational structure and size of the firm.

This study assumes that a portion of manager's and officeworkers' salaries are alloted for the dehydration operation. The rest should be allocated to harvesting, trucking, storage, and sales. Administrative costs ranged from 61 cents for Model A to 23 cents for Model F, or 8 to 10 percent of total fixed costs.

The plant supervisor's salary was also prorated to the major areas of responsibility. The smaller models were assigned $4,000, and larger models, $5,000. This means that approximately half the supervisor's time was allocated for the dehydration and pelleting operations of the plant. This accounted for a slightly larger portion of fixed costs than administrative costs.

Variable

Variable costs as used in these models include labor, utilities, maintenance and repair, and additive. These expense items are a function of the plant's output.

Labor costs.--Annual labor costs in the models range from $17,590 for Model A to $34,730 for Model F (table 3). Model F requires the lowest per ton cost, $2, and Model A, the highest, $3.55. These estimates included both production and maintenance labor costs. Labor accounts for 24 to 29 percent of the variable costs.

Utilities.--The major cost for all models, ranges from $28,390 for Model A to $77,880 for Model F (table 3). Utility costs comprise 40 to 50 percent of the total variable costs.

Natural gas, by far the largest of the three utility costs, ranges from $3.28 a ton for Model A to $3.06 for Model F. Natural gas accounts for, on the average, about two-thirds of the total utility cost for all models. The remaining third is, for the most part, electricity. Electricity per ton ranges from $2.41 a ton for the smallest plant to $1.40 for the largest plant (table 5). Water cost was insignificant in all models.

Maintenance and repairs.--The cost of maintenance, replacement parts for equipment, and services hired by the plant to make repairs varies. It is assumed to be 7 percent of the total investment cost. Cost per ton decreases with the increased size of the plant. Model A has the highest cost, $2.58 a ton. Maintenance costs for this model are greater than electricity costs. However, as plant size and output increase, the maintenance cost decreases faster per ton than the cost of electricity. Model F has maintenance and repair costs of $1.27 per ton--about half of Model A's cost.

Additive.--The addition of an antioxidant is considered optional by many in the industry. However, upon removal from inert gas storage, alfalfa immediately begins to lose carotene and xanthophyll. To inhibit this loss, the meal should by sprayed during pelleting with an antioxdant. Cost of the antioxidant has been estimated by the industry to be 50 cents per ton.

Total

Total operating costs for these models range from $90,910 for Model A to $190,820 for Model F (table 3). With output increased 3½ times, the costs for Model F are slightly more than double those of the smaller model.

Table 5.--Electricity costs, by operation, for all models

Item	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Receiving:						
Annual cost......	250	320	380	410	520	600
Cost per ton.....	.05	.06	.04	.04	.03	.03
Dehydrating:						
Annual cost......	3,570	3,890	4,570	5,150	5,880	7,000
Cost per ton.....	.72	.67	.50	.44	.40	.40
Grinding:						
Annual cost......	5,120	5,450	6,130	7,160	7,850	9,080
Cost per ton.....	1.03	.94	.68	.62	.53	.52
Pelleting:						
Annual cost......	2,820	3,260	3,930	4,770	6,100	7,050
Cost per ton.....	.57	.57	.43	.41	.41	.41
Loading out:						
Annual cost......	50	60	80	100	130	150
Cost per ton.....	.01	.01	.01	.01	.01	.01
Miscellaneous:						
Annual cost......	150	170	250	310	420	460
Cost per ton.....	.03	.03	.03	.03	.03	.03
Total:						
Annual cost......	11,960	13,150	15,340	17,900	20,900	24,340
Cost per ton.....	2.41	2.28	1.69	1.55	1.41	1.40

Total operating costs vary widely with the increased size of operation. Costs vary from \$18.37 a ton in Model A to \$11.01 a ton in Model F. There appear to be some economies of scale in alfalfa dehydration: As hourly output increases from 1½ tons per hour to 5¼ tons per hour, the total cost per ton declines about 40 percent.

Fixed costs for the models range from 33 to 24 percent of total costs. As plant size becomes larger, fixed costs take less of a share of the total operating cost per ton. Fixed costs declined over 50 percent between the smallest and the largest models. Variable costs on the other hand decrease only about one-third.

AIR SEPARATION MILLING

Separation is not entirely new to the alfalfa dehydrating industry. About 20 or 30 years ago, some dehydrators attempted separation by grinding through

screens of varying coarseness or fineness. Many problems were created with this grinding, sifting method, and it was soon abandoned in most plants.

Recent research on alfalfa separation has produced a possible solution for alfalfa dehydrators. The cooperative research of the Field Crops Laboratory of USDA's Western Utilization Research and Development Division and the Nebraska Department of Economic Development has developed what appears to be a feasible method for alfalfa separation (11). USDA's Economic Research Service was asked to make an economic evaluation of the newly tried air separation approach. This study describes the basic costs which were synthesized in using the economic model approach.

Milling Procedure

Our technique of tailoring dehydrated alfalfa products to suit the users involves air separation. Dehydrated alfalfa is taken from the dehydrating drum and passed through a large fan (fig. 2). It is carried to the cooling cyclone and then dropped into the separation system through a feed conveyor and rotary valve. This rotary valve is necessary to preclude the entrance of air to the column at any point other than the open bottom of the column. The top of the column is attached to a transition piece, reaching from the column to the tangential opening on a cyclone collector.

The cyclone is a negative air type with a rotary outlet valve at the bottom of the cone and a suction pipe out of the top, and is connected to a blower. As the blower operates, air is sucked from the cyclone, through the transition piece and up through the vertical column. As the chops fall into this air current, light particles are drawn upward and across the transition, into the cyclone, and out through the rotary valve at the bottom of the cone. The heavy particles fall through the air current and fall free from the bottom of the column.

Uniformity of feed rate is of considerable importance in any manufacturing process utilizing various types of machinery and equipment to produce one or more finished products. Concerning alfalfa, the best operation can be obtained when the green chop is uniformly cut and has no long stems. Efficient dehydrator operation as well as air separation is closely related to the uniformity of the green chop.

It is important that the dried leaves of the plant be well shattered before entering the separator. This is fairly well accomplished by passing the material through the fan of a positive pneumatic system, which blows it from dehydrator to cyclone. If a negative air system were used, it would be essential to pass the dried material through a fan or a hammermill to do this job. Even distribution of the feed across the top of the air separator column is important for best results. For good distribution, a "kicker" should be installed below the rotary inlet valve to break up any agglomeration which might occur.

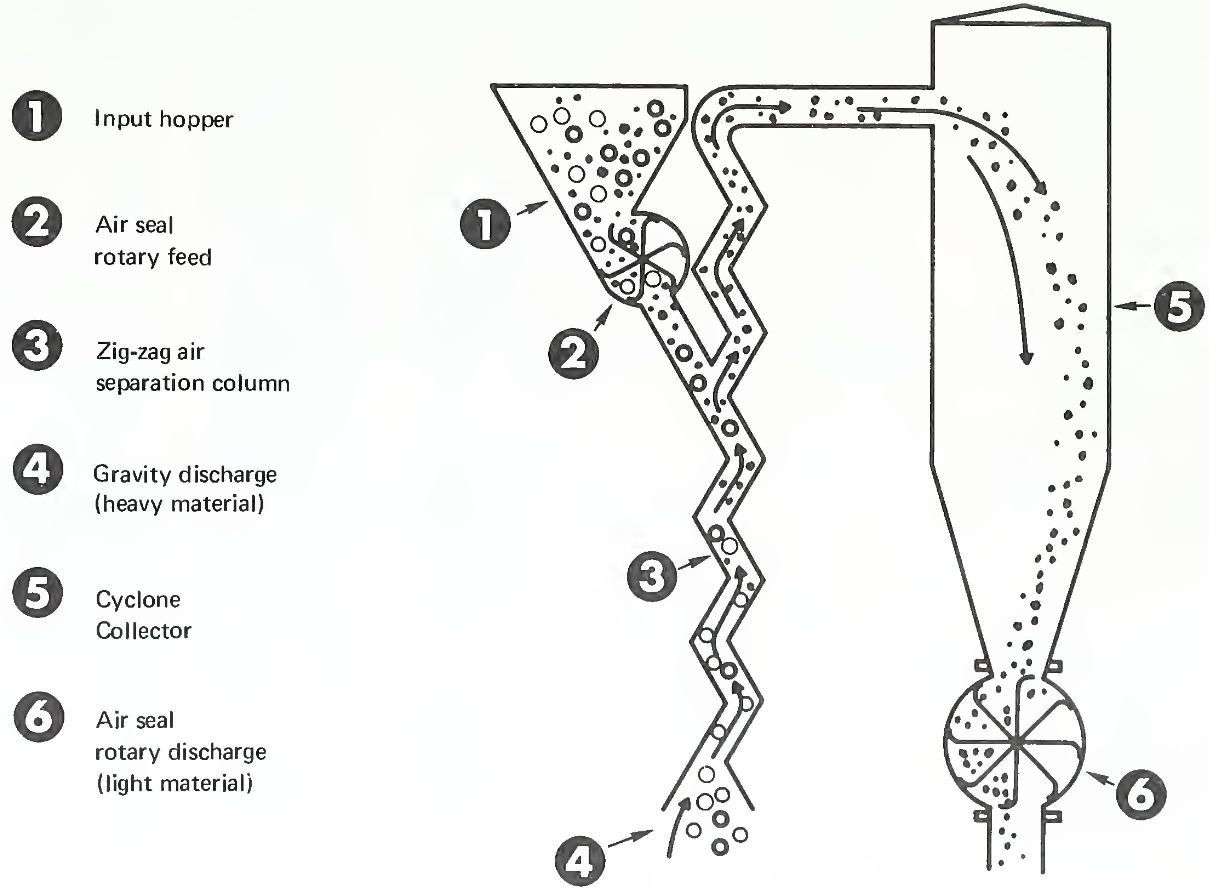

Figure 2. -- Diagram of separation system used with permission of Scientific Separators, Inc., Denver, Colo., so that readers may know how test results were obtained. USDA neither warrants nor guarantees the standard of the equipment, and use of the name implies no approval of the equipment to the exclusion of others that may also be suitable.

Separation in Models

With the equipment information and cost data presented thus far, it is now possible to estimate the costs incurred in leaf separation. Three different size separation units are suitable for the six models (table 6). The smaller separation unit with a capacity of about 2 tons of dry material an hour is used with Models A and B. Models C and D use a larger separator with the capacity of about 4 tons per hour. The largest model separator with the hourly capacity of 5¼ tons per hour is used for Models E and F. Field tests have demonstrated that dehydrated alfalfa can be effectively separated into fine and coarse fractions.

Table 6.--Air separation systems 1/

Tons per hour	Column	Motors		Approximate cost
		Blower	Other	
	Size	- - Horsepower - -		Dollars
2................	6" x 65" x 10'6"	3	3 1/2	9,000
4................	2/ 6" x 65" x 11'6"	6	3 1/2	13,000
5.2..............	2/ 8" x 65" x 14'	8 1/2	3 3/4	14,000

1/ Other systems with smaller and larger capacities are available.
2/ These units are dual columns: 12" x 65" x 11' and 16" x 65" x 14'.

Equipment and facility costs for the three alternative separation systems are shown in tables 7, 8, and 9. The receiving and dehydrating operations remain essentially the same for all systems. Major changes involve grinding and installation of a second pelleting system. All separation systems should have two pelleting systems, for fine and coarse meal.

During field testing, researchers assessed several alternative production techniques which might be included in a system. Dehydrated material must be passed through a fan to shatter the leaf portion from the stem. As the dried material leaves the dehydrator, the leaf portion may contain 2 to 4 percent moisture, while the stems contain 10 to 12 percent. A slight differential grinding is required at this point to insure adequate separation. In effect, this means that a positive air system is essential for separation, or that differential grinding equipment must be added if a negative system is employed.

It was also proposed that a very light milling of the dehydrated meal might be done prior to its entering the separator. This would tend to eliminate long stems and aid in separation. Also it would greatly reduce the electricity requirements for pelleting the coarse fraction. However, there may be a disadvantage: the intermediate milling operation would tend to equilibrate moisture content. Moisture would be reduced in the stem portions and their density would be reduced. In other words, the stem particles would become lighter and respond to air currents in the same way as leaf--separation would be impossible.

Table 7.--Separation alternative I, equipment and facility costs: Six models

Cost item	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Equipment:						
Receiving........	13,900	14,300	13,900	14,300	14,300	14,700
Dehydrating......	36,500	48,300	44,900	59,500	59,000	90,000
Separating 1/....	9,000	9,000	13,000	13,000	14,000	14,000
Pelleting (fine).	34,100	34,100	34,100	34,100	40,800	40,800
Pelleting (coarse) 1/.....	37,900	37,900	37,900	37,900	39,900	39,900
Loading out......	8,000	8,000	11,600	11,600	15,200	15,200
Miscellaneous....	2,500	2,500	3,500	3,500	4,000	4,000
Total..........	141,900	154,100	158,900	173,900	187,200	218,600
Installing equipment.........	42,600	46,250	47,700	52,200	56,200	65,600
Facilities:						
Mill building and boilerroom..	19,700	19,700	25,700	25,700	29,500	29,500
Office and shop..	9,600	9,600	14,500	14,500	18,900	18,900
Loading out tanks...........	32,400	32,400	43,800	43,800	45,200	45,200
Total..........	61,700	61,700	84,000	84,000	93,600	93,600
Grand total..	246,200	262,050	290,600	310,100	337,000	377,800

1/ Major additions to models in table 2, grinding equipment excluded.

Table 8.--Separation alternative II, equipment and facility costs: Six models

Cost item	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Equipment:						
Receiving	13,900	14,300	13,900	14,300	14,300	14,700
Dehydrating	36,500	48,300	44,900	59,500	59,000	90,000
Grinding	9,800	9,800	11,500	11,500	12,100	13,100
Separating 1/	9,000	9,000	13,000	13,000	14,000	14,000
Pelleting (fine)	34,100	34,100	34,100	34,100	40,800	40,800
Pelleting (coarse) 1/	37,900	37,900	37,900	37,900	39,900	39,900
Loading out	8,000	8,000	11,600	11,600	15,200	15,200
Miscellaneous	2,500	2,500	3,500	3,500	4,000	4,000
Total	151,700	163,900	170,400	185,400	199,300	231,700
Installing equipment	45,550	49,200	51,200	55,700	59,800	69,600
Facilities:						
Mill building and boilerroom	19,700	19,700	25,700	25,700	29,500	29,500
Office and shop	9,600	9,600	14,500	14,500	18,900	18,900
Loading out tanks	32,400	32,400	43,800	43,800	45,200	45,200
Total	61,700	61,700	84,000	84,000	93,600	93,600
Grand total	258,950	274,800	305,600	325,100	352,700	394,900

1/ Major additions to models in table 2.

Table 9.--Separation alternative III, equipment and facility costs: Six models

Cost item	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Equipment:						
Receiving........	13,900	14,300	13,900	14,300	14,300	14,700
Dehydrating......	36,500	48,300	44,900	59,500	59,000	90,000
Separating 1/....	9,000	9,000	13,000	13,000	14,000	14,000
Grinding (coarse) 1/.....	9,800	9,800	9,800	9,800	11,500	11,500
Pelleting (coarse) 1/.....	37,900	37,900	37,900	37,900	39,900	39,900
Pelleting (fine).	34,100	34,100	34,100	34,100	40,800	40,800
Loading out......	8,000	8,000	11,600	11,600	15,200	15,200
Miscellaneous....	2,500	2,500	3,500	3,500	4,000	4,000
Total..........	151,700	163,900	168,700	183,700	198,700	230,100
Installing equipment.........	45,550	49,200	50,650	55,150	59,650	67,900
Facilities:						
Mill building and boilerroom..	19,700	19,700	25,700	25,700	29,500	29,500
Office and shop..	9,600	9,600	14,500	14,500	18,900	18,900
Loading out tanks...........	32,400	32,400	43,800	43,800	45,200	45,200
Total..........	61,700	61,700	84,000	84,000	93,600	93,600
Grand total..	258,950	274,800	303,350	322,850	351,950	391,600

1/ Major additions to models in table 2. Smaller grinding unit is used since only coarse fraction is ground.

Researchers also suggested an alternative method that might be used. The material would be passed through a positive air system fan and on to the separator. The leaf portion would go directly to the pellet mill but the coarse fraction would undergo light milling prior to pelleting. A hammermill would be placed in the coarse stream, as in alternative III, to produce the light milling effect. Care should be taken to see that stem particles are 3/8 to 1/2 inch long. This grinding will reduce the amount of grinding performed by the pellet mill and will increase its efficiency.

Alternative I, table 7, does not include grinding equipment since the material is passed through a transfer fan. Leaves are fragile at this point and would be shattered. This fan provides adequate differential grinding action to separate the leaves from the petioles. After the fractions are separated, each is deposited in a meal bin over a pellet mill. The fine material is made into 1/4-inch pellets and moved by a pneumatic system from the cooler to the loadout tanks. Coarse material is made into 3/4-inch cubes and is moved to loadout tanks from the pellet cooler via a mechanical conveying system.

Alternative II, table 8, has the same basic equipment in the receiving, dehydrating, and grinding operations as the standard model. The separation process is added to the system following the grinding, and the remaining equipment is essentially the same as in alternative I.

In alternative III, table 9, the receiving, dehydrating, and separating equipment is similar to that used in alternative I. From the separator, the fine fraction moves to the pellet mill, and the coarse fraction is diverted to the grinder. The coarse fraction is ground and then moved to the pelleting operation and on to loadout tanks. Many believe that the length of the fibrous material in the coarse fraction should be no longer than 1/2 inch in length to produce a quality pellet.

Additional Investment

All three alternative separation systems require additional equipment and facilities. With separation, there are two major products to handle instead of one with the conventional dehydration process. There will, of course, be several grades of pellet and cube, since differences in quality will still exist to a certain degree.

Equipment and facility costs are summarized in table 10 for the three alternatives and are compared with the standard models. Except for alternatives II and III, Models A and B, alternative I is the least expensive and alternative II is the most expensive. These differences are shown in more detail in appendix B. Essentially, the increased costs are due to the addition of the separation equipment, a second pelleting system, and an increase in number of bins to maintain separate products. Alternative I is the least expensive because grinding equipment was excluded from this system.

Total investment costs for separation alternatives range from $246,200 for Model A in alternative I to $394,900 for Model F in alternative II (table 10). A comparison of each model's cost between the standard and the highest cost alternative shows that as plants increase in size the added cost decreases.

Table 10.--Equipment and facility costs: Model plants with and without separation

Model and cost item	No separation	Separation		
	Standard	Alternative I	Alternative II	Alternative III
	Dollars			
Model A:				
Equipment cost...	131,000	184,500	197,250	197,250
Facility cost....	51,200	61,700	61,700	61,700
Total..........	182,200	246,200	258,950	258,950
Model B:				
Equipment cost...	146,900	200,350	213,100	213,100
Facility cost....	51,200	61,700	61,700	61,700
Total..........	198,100	262,050	274,800	274,800
Model C:				
Equipment cost...	156,500	206,600	221,600	219,350
Facility cost....	69,200	84,000	84,000	84,000
Total..........	225,700	290,600	305,600	303,350
Model D:				
Equipment cost...	176,400	226,100	241,100	238,850
Facility cost....	69,200	84,000	84,000	84,000
Total..........	245,600	310,100	325,100	322,850
Model E:				
Equipment cost...	187,000	243,400	259,100	258,350
Facility cost....	85,800	93,600	93,600	93,600
Total..........	272,800	337,000	352,700	351,950
Model F:				
Equipment cost...	227,600	284,200	301,300	298,000
Facility cost....	85,800	93,600	93,600	93,600
Total..........	313,400	377,800	394,900	391,600

For example, in Model A increased investment for the highest separation system was 42 percent above the standard. However, in Model F the increase between the standard and alternative II was 26 percent. The dollar increase ranges from about $64,000 for Model A up to $81,500 for Model F.

Costs between Model A and Model F for alternative I and alternative II increased about 53 percent while alternative III increased slightly less--51 percent with increased plant size. The standard models have a 72-percent increase between the lowest and highest cost models.

Operating Costs

Operating costs for the three alternatives and the standard models are summarized in table 11. However, tables 12 through 14 provide considerable detail for the major cost items.

Fixed

Fixed costs account for 25 to 40 percent of total operating costs for all models. The extremes are both found in the standard model costs. All separation methods show fixed costs accounting for 27 to 37 percent of their total costs.

Depreciation.--Depreciation is by far the largest fixed cost in these models. Total depreciation for equipment and facilities in the standard model ranges from $2.23 to $1.10 (table 15). Depreciation in the alternative models ranges between $3.22 to $1.33. Depreciation accounts for about 40 percent of fixed costs in all models. As plant size increases, depreciation per ton decreases. Standard models decrease about 50 percent between Models A and F, whereas separation models decline about 44 percent. Equipment depreciation accounts for around 80 percent of total depreciation for all models.

Interest.--This is the second largest item of fixed costs for these models. Interest ranges from $1.95 a ton for Model A, alternatives II and III, to 80 cents for Model F, alternative I, which has the lowest cost of all separation models. The standard ranges from $1.41 to $0.67 per ton. Generally, interest cost will average approximately 25 percent of the total fixed costs.

Other fixed costs.--Administration costs and supervisory salary remain the same for all models. The cost per ton does not change with separation alternations. Model A has a combined cost of $1.42 per ton and Model F, $0.52. Administrative and supervisory costs account for 15 to 25 percent of total fixed costs. Insurance and taxes make up the remaining 13 to 17 percent.

Variable

Variable costs make up by far the greatest portion of operating costs--60 to 75 percent of the total costs.

Table 11.--Comparison of fixed, variable, and total costs per ton: Model plants with and without separation

Model and cost item	No separation	Separation		
	Standard	Alternative I	Alternative II	Alternative III
	Dollars			
Model A:				
Fixed	6.01	7.59	7.92	7.92
Variable	12.36	12.48	13.69	13.18
Total	18.37	20.07	21.61	21.10
Difference	--	1.70	3.24	2.73
Model B:				
Fixed	5.49	6.84	7.13	7.12
Variable	11.61	11.58	12.63	12.19
Total	17.10	18.42	19.76	19.31
Difference	--	1.32	2.66	2.21
Model C:				
Fixed	3.96	4.81	5.03	5.00
Variable	9.92	9.97	10.75	10.39
Total	13.88	14.78	15.78	15.39
Difference	--	.90	1.90	1.51
Model D:				
Fixed	3.32	4.00	4.15	4.14
Variable	9.29	9.35	10.06	9.74
Total	12.61	13.35	14.21	13.88
Difference	--	.74	1.60	1.27
Model E:				
Fixed	2.86	3.39	3.52	3.52
Variable	8.72	8.67	9.22	8.98
Total	11.58	12.06	12.74	12.50
Difference	--	.48	1.16	.92
Model F:				
Fixed	2.75	3.20	3.33	3.31
Variable	8.26	8.11	8.71	8.41
Total	11.01	11.31	12.04	11.72
Difference	--	.30	1.03	.71

Table 12.--Operating costs for all models using separation alternative I

Cost item	Model A		Model B		Model C		Model D		Model E		Model F	
	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton
	Dollars											
Fixed costs												
Administrative	3,000	0.61	3,000	0.52	3,500	0.39	3,500	0.30	4,000	0.27	4,000	0.23
Salary (Supervisor)	4,000	.81	4,000	.69	4,500	.50	4,500	.39	5,000	.34	5,000	.29
Depreciation 1/	15,100	3.05	16,160	2.79	17,580	1.93	18,880	1.64	20,430	1.37	23,150	1.33
Insurance 2/	2,470	.50	2,620	.45	2,910	.32	3,110	.27	3,370	.23	3,780	.22
Taxes 3/	3,820	.77	4,050	.70	4,480	.49	4,780	.41	5,180	.35	5,790	.33
Interest 4/	9,180	1.85	9,740	1.69	10,740	1.18	11,420	.99	12,360	.85	13,790	.80
Total	37,570	7.59	39,570	6.84	43,710	4.81	46,190	4.00	50,340	3.39	55,510	3.20
Variable costs												
Labor 5/	17,590	3.55	17,590	3.04	24,720	2.72	29,340	2.54	34,730	2.34	34,730	2.00
Utilities:												
Natural gas 6/	16,240	3.28	19,350	3.35	29,500	3.24	36,730	3.18	46,780	3.15	53,020	3.06
Electricity 7/	8,070	1.63	8,550	1.48	11,250	1.24	14,100	1.22	15,750	1.06	17,160	.99
Water	190	.04	210	.04	300	.03	340	.03	450	.03	520	.03
Maintenance and repairs 8/	17,240	3.48	18,350	3.17	20,350	2.24	21,710	1.88	23,600	1.59	26,450	1.53
Additive 9/	2,480	.50	2,890	.50	4,540	.50	5,780	.50	7,430	.50	8,670	.50
Total	61,810	12.48	66,940	11.58	90,660	9.97	108,000	9.35	128,740	8.67	140,550	8.11
Grand total	99,380	20.07	106,510	18.42	134,370	14.78	154,190	13.35	179,080	12.06	196,060	11.31

1/ Depreciation; straight line method: Equipment 15 years; bins and tanks, 20 years; buildings 25 years.
2/ Insurance: $1 per $100 initial investment.
3/ Taxes: 1½ percent initial investment.
4/ Interest: 7 percent on ½ average investment, 7 percent on land value.
5/ Labor: Average for mill labor $2, maintenance labor $2.30. (Includes 30 cents for fringe benefits.)
6/ Natural gas: 31 cents per 1,000 cubic feet.
7/ Electricity: 1.5 cents per kilowatt hour.
8/ Maintenance and repairs: 7 percent of initial investment.
9/ Additive: Cost of antioxidant application estimated at 50 cents per ton.

Table 13.--Operating costs for all models using separation alternative II

Cost item	Model A		Model B		Model C		Model D		Model E		Model F	
	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton
	Dollars											
Fixed costs												
Administrative	3,000	0.61	3,000	0.52	3,500	0.39	3,500	0.30	4,000	0.27	4,000	0.23
Salary (Supervisor)	4,000	.81	4,000	.69	4,500	.50	4,500	.39	5,000	.34	5,000	.29
Depreciation 1/	15,950	3.22	17,010	2.94	18,580	2.04	19,880	1.72	21,480	1.44	24,290	1.40
Insurance 2/	2,590	.52	2,750	.48	3,060	.34	3,260	.28	3,530	.24	3,950	.23
Taxes 3/	4,010	.81	4,250	.74	4,710	.52	5,000	.43	5,410	.36	6,050	.35
Interest 4/	9,630	1.95	10,190	1.76	11,260	1.24	11,940	1.03	12,910	.87	14,390	.83
Total	39,180	7.92	41,200	7.13	45,610	5.03	48,080	4.15	52,330	3.52	57,680	3.33
Variable costs												
Labor 5/	17,590	3.55	17,590	3.04	24,720	2.72	29,340	2.54	34,730	2.34	34,730	2.00
Utilities:												
Natural gas 6/	16,240	3.28	19,350	3.35	29,500	3.24	36,730	3.18	46,780	3.15	53,020	3.06
Electricity 7/	13,170	2.66	13,690	2.37	17,340	1.91	21,260	1.84	22,870	1.54	26,340	1.52
Water	190	.04	210	.04	300	.03	340	.03	450	.03	520	.03
Maintenance and repairs 8/	18,130	3.66	19,240	3.33	21,400	2.35	22,760	1.97	24,690	1.66	27,650	1.60
Additive 9/	2,480	.50	2,890	.50	4,540	.50	5,780	.50	7,430	.50	8,670	.50
Total	67,800	13.69	72,970	12.63	97,800	10.75	116,210	10.06	136,950	9.22	150,930	8.71
Grand total	106,980	21.61	114,170	19.76	143,410	15.78	164,290	14.21	189,280	12.74	208,610	12.04

1/ Depreciation; straight line method: Equipment 15 years; bins and tanks, 20 years; buildings 25 years.
2/ Insurance: $1 per $100 initial investment.
3/ Taxes: 1½ percent initial investment.
4/ Interest: 7 percent on ½ average investment, 7 percent on land value.
5/ Labor: Average for mill labor $2, maintenance labor $2.30. (Includes 30 cents for fringe benefits.)
6/ Natural gas: 31 cents per 1,000 cubic feet.
7/ Electricity: 1.5 cents per kilowatt hour.
8/ Maintenance and repairs: 7 percent of initial investment.
9/ Additive: Cost of antioxidant application estimated at 50 cents per ton.

Table 14.--Operating costs for all models using separation alternative III

Cost item	Model A		Model B		Model C		Model D		Model E		Model F	
	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton
	Dollars											
Fixed costs												
Administrative	3,000	0.61	3,000	0.52	3,500	0.39	3,500	0.30	4,000	0.27	4,000	0.23
Salary (supervisor)	4,000	.81	4,000	.69	4,500	.50	4,500	.39	5,000	.34	5,000	.29
Depreciation 1/	15,950	3.22	17,010	2.94	18,430	2.03	19,730	1.71	21,430	1.44	24,070	1.39
Insurance 2/	2,590	.52	1,750	.48	3,040	.33	3,230	.28	3,520	.24	3,920	.23
Taxes 3/	4,010	.81	4,240	.73	4,680	.52	4,970	.43	5,400	.36	6,010	.35
Interest 4/	9,630	1.95	10,180	1.76	11,180	1.23	11,860	1.03	12,870	.87	14,270	.82
Total	39,180	7.92	41,180	7.12	45,330	5.00	47,790	4.14	52,220	3.52	57,270	3.31
Variable costs												
Labor 5/	17,590	3.55	17,590	3.04	24,720	2.72	29,340	2.54	34,730	2.34	34,730	2.00
Utilities:												
Natural gas 6/	16,240	3.28	19,350	3.35	29,500	3.24	36,730	3.18	46,780	3.15	53,020	3.06
Electricity 7/	10,640	2.15	11,150	1.93	14,160	1.56	17,680	1.53	19,310	1.30	21,490	1.24
Water	190	.04	210	.04	300	.03	340	.03	450	.03	520	.03
Maintenance and repairs 8/	18,130	3.66	19,240	3.33	21,240	2.34	22,600	1.96	24,640	1.66	27,420	1.58
Additive 9/	2,480	.50	2,890	.50	4,540	.50	5,780	.50	7,430	.50	8,670	.50
Total	65,270	13.18	70,430	12.19	94,460	10.39	112,470	9.74	133,340	8.98	145,850	8.41
Grand total	104,450	21.10	111,610	19.31	139,790	15.39	160,260	13.88	185,560	12.50	203,120	11.72

1/ Depreciation; straight line method: Equipment 15 years; bins and tanks, 20 years; building 25 years.
2/ Insurance: \$1 per \$100 initial investment.
3/ Taxes: 1½ percent initial investment.
4/ Interest: 7 percent on ½ average investment, 7 percent on land value.
5/ Labor: Average for mill labor \$2, maintenance labor \$2.30. (Includes 30 cents for fringe benefits.)
6/ Natural gas: 31 cents per 1,000 cubic feet.
7/ Electricity: 1.5 cents per kilowatt hour.
8/ Maintenance and repairs: 7 percent of initial investment.
9/ Additive: Cost of antioxidant application estimated at 50 cents per ton.

Table 15.--Depreciation costs: Model plants with and without separation

Model and cost item	Method of operation: No separation — Standard	Separation — Alternative I	Separation — Alternative II	Separation — Alternative III
	Dollars			
Model A:				
Equipment cost	131,000	184,500	197,250	197,250
Depreciation per ton	1.77	2.48	2.65	2.65
Facility cost	51,200	61,700	61,700	61,700
Depreciation per ton	.46	.57	.57	.57
Total	2.23	3.05	3.22	3.22
Model B:				
Equipment cost	146,900	200,350	213,100	213,100
Depreciation per ton	1.69	2.31	2.46	2.46
Facility cost	51,200	61,700	61,700	61,700
Depreciation per ton	.40	.48	.48	.48
Total	2.09	2.79	2.94	2.94
Model C:				
Equipment cost	156,500	206,600	221,600	219,350
Depreciation per ton	1.15	1.52	1.63	1.62
Facility cost	69,200	84,000	84,000	84,000
Depreciation per ton	.34	.41	.41	.41
Total	1.49	1.93	2.04	2.03
Model D:				
Equipment cost	176,400	226,100	241,100	238,850
Depreciation per ton	1.02	1.31	1.39	1.38
Facility cost	69,200	84,000	84,000	84,000
Depreciation per ton	.27	.33	.33	.33
Total	1.29	1.64	1.72	1.71
Model E:				
Equipment cost	187,000	243,400	259,100	258,350
Depreciation per ton	.84	1.09	1.16	1.16
Facility cost	85,000	93,600	93,600	93,600
Depreciation per ton	.26	.28	.28	.28
Total	1.10	1.37	1.44	1.44
Model F:				
Equipment cost	227,600	284,200	301,300	298,000
Depreciation per ton	.88	1.09	1.16	1.15
Facility cost	85,800	93,600	93,600	93,600
Depreciation per ton	.22	.24	.24	.24
Total	1.10	1.33	1.40	1.39

Utility costs.--Utility costs account for 25 to 40 percent of total variable costs for all models. Natural gas accounts for 55 to 75 percent of total utility costs (table 16). Natural gas varies between $3.06 and $3.35 per ton.

Electricity accounts for most of the remaining utility costs. Water costs less than other utilities. Electricity costs range from $0.99 per ton in alternative I, Model F to $2.66 per ton in the alternative II, Model A. Alternative I costs are much lower than those for the other alternatives because alternative I does not include the grinding, which consumes a great deal of electricity. Alternative III is less expensive than the standard because only half the output is ground, so a smaller grinder that requires less electricity is used.

Labor.--Labor requirements for all models are essentially the same as for the standard models. Labor cost ranges from $3.55 per ton for Model A to $2 a ton for Model F, and accounts for 24 to 29 percent of all variable costs.

Maintenance and repairs.--These costs are also high, ranging from $3.66 to $1.53 per ton for the separation models--higher than the costs for standard models ot $2.58 to $1.27 per ton. With added equipment for separation, more care is required for preventive maintenance and replacement of parts.

Additive.--An average cost of 50 cents per ton for antioxidant application was added to all models. This is not a major variable cost.

Total

Separation models have higher operating costs, because the separation process increases equipment and facility costs.

Alternative I has the lowest cost of the three alternatives; costs ranged from $20.07 to $11.31 per ton (table 11). Alternative II has the highest operating costs, from $21.61 to $12.04. Alternative III has costs somewhat greater than the average of the two extremes.

Increases in total costs among the alternative and standard models are not uniform. Alternative I costs range from 9 percent higher than standard in Model A to 2 percent higher in Model F. Alternative II costs range from 18 to 9 percent. These differences will be brought out in a later discussion of various cost items.

The differences may be compared by another method. Table 11 shows the differences between alternative costs and the standard model's costs. The most expensive separation system is alternative II Model A, which is $3.24 above the standard cost. The least expensive operation is Model F in alternative I. Economies of scale operate with the models, since savings are realized with each larger model used. In alternative I, the difference in operating costs decreases significantly between Models A and F. Increased volume and efficient operations cut the difference from $1.70 to $0.30 per ton, a decrease of about 80 percent. Alternatives II and III decreased about 70 percent between Models A and F.

Table 16.--Utility cost per ton for all models 1/

Model and cost item	No separation	Separation		
	Standard	Alternative I	Alternative II	Alternative III
	Dollars			
Model A:				
Electricity	2.41	1.63	2.66	2.15
Natural gas	3.28	3.28	3.28	3.28
Total	5.69	4.91	5.94	5.43
Model B:				
Electricity	2.28	1.48	2.37	1.93
Natural gas	3.35	3.35	3.35	3.35
Total	5.63	4.83	5.72	5.28
Model C:				
Electricity	1.69	1.24	1.91	1.56
Natural gas	3.24	3.24	3.24	3.24
Total	4.93	4.48	5.15	4.80
Model D:				
Electricity	1.55	1.22	1.84	1.53
Natural gas	3.18	3.18	3.18	3.18
Total	4.73	4.40	5.02	4.71
Model E:				
Electricity	1.41	1.06	1.54	1.30
Natural gas	3.15	3.15	3.15	3.15
Total	4.56	4.21	4.69	4.45
Model F:				
Electricity	1.40	.99	1.52	1.24
Natural gas	3.06	3.06	3.06	3.06
Total	4.46	4.05	4.58	4.30

1/ Cost of water not included.

Feasibility of Separation

In the previous section, the costs of three alternative separation methods were compared with standard or conventional model plants. Certain basic factors must be reviewed and weighed to determine feasibility.

Of the higher operating costs with separation, alternative I has the smallest per ton increases and alternative II has the greatest increase. Per ton costs increase with more elaborate systems. Alternative I is by far the least expensive. Alternative II is the most expensive separation method for all models.

Alternative I may appear to be the system most likely to be accepted by the industry. As mentioned before, the additional cost is less than for the other systems, but it does not have the flexibility of alternative II. Flexibility alone could mean more to efficient operation than the differences in operating costs of the two systems.

Alternative II could be designed to operate with or without separation. A dehydrator may wish not to separate the entire crop, and let his market dictate the production pattern over the season. With alternatives I and III, he must separate the entire output. Alternative III has one distinct advantage--the coarse fraction may be ground smaller.

Some livestock feeders as well as dehydrators prefer to reduce the coarse fraction to ½ inch or less in length. This will make a better pellet at lower cost. Most agree that a pellet mill does not make the most efficient grinder. Alternative III will have some application to certain dehydration operations, but its use will no doubt be more limited than either I or II.

Air systems for separation of high-protein leaf from lower protein stem are practical and low-cost in themselves; they have the advantage of controlling considerable variations in the quality of end-products by single adjustments which require no shutdown. They lend themselves well to the production of moderate amounts of high-grade leaf, accompanied by a stem fraction of standard market grade or the production of a strictly roughage grade of stem fraction with a moderately improved leaf fraction. Between those two extremes lie many choices to satisfy the demands of the dehydrator and his market.

By use of the separation process, longer cutting cycles can be adopted which will lead to increased yields per acre and possibly lengthen the life of the stand. The longer cutting cycles will include chopped alfalfa with a lower moisture content which will in turn result in lower dehydration costs. The inconveniences of hazardous weather are reduced since the dehydrator can utilize the crop even if harvesting must be delayed due to rain or crowding of schedules.

Researchers have demonstrated that with low-grade alfalfa hay (14 percent protein) it is possible to dehydrate and air separate at least a fourth of the total product as a standard 17-percent product. If a hay of 18-percent protein were used it would be possible to recover 30 percent of this total as a 25-percent protein fine fraction. This would leave 70 percent of the total as coarse fraction of 15-percent protein. Both of these grades would fall into standard market catagories.

During field testing of the separation equipment, researchers tried to determine the effect of higher air velocities on product separation. A wide range of velocities was used to determine an optimum range of peak where the greatest efficiency may be obtained. Researchers consider that 700 linear feet per minute might provide the best division of leaf and stem.

Commercial dehydrators differ in their demands of the process. Some want a small fraction of high-grade leaf meal which in most cases would leave a 15- or 17-percent protein coarse fraction. Others may want to obtain a large fine fraction of lesser protein content, leaving a coarse fraction practically free of leaf. Still others may wish to obtain as much as possible of a 17-percent protein product from feed which grades below present market grades.

STORAGE

Dehydrated alfalfa is produced seasonally but is used throughout the year. Alfalfa dehydrators either store a portion of their production or sell it as soon as possible. Many firms have joined or set up cooperative storage facilities with other firms.

Dehydrated alfalfa is relatively unstable under ordinary storage conditions. Nutrients are rapidly lost from alfalfa after harvest. In past years, a number of processes which would reduce losses have been tried. Refrigerated storage helped but proved very expensive. Use of inert gas has increased greatly during the past 10 years since it is cheaper than refrigeration. Antioxidants have been used since the early sixties. Many dehydrators are using an antioxidant because preservation of grade and quality is very important. This will be even more important in the future as grades are improved by air separation or some other method.

Many alfalfa dehydrators ask: "Is it less expensive to store at the plant than it is in a large cooperative facility?" This section will analyze the storage costs for each model discussed in the study. The study assumed gas storage is available for about 60 percent of the plant output.

Inert Gas Storage

Preservation of the vitamins and other nutrients in pelleted alfalfa during storage necessitates the blanketing of storage tanks with inert gas. Over the years, generators that are especially suited for this application have been developed. Whether there are a few tanks to fill or a very large installation, generators of the proper capacity and design are available.

Best retention of vitamins and nutrients is obtained where least oxygen is present in the storage space. Four things are important to ensure this: (1) a dependable generator providing inert gas of stable composition and high quality; (2) tight storage tanks and proper gas distribution to the tanks and circulation within them; (3) a good procedure for purging air (oxygen) prior to filling and then maintaining the inert gas blanket during storage and withdrawal; and (4) sufficient inert gas generator capacity.

The generator automatically adjusts to capacity requirements. It will operate at full rated capacity when purging the tanks before filling them. After the tanks are filled and closed and a lower volume of inert gas is needed, the machine automatically cuts back.

The discharge temperature of the inert gas will be approximately 15° F. above the temperature of the inlet cooling water. Inert gas is saturated with water vapor at this discharge temperature. When the gas passes through colder piping, additional water condenses and if the piping is below freezing, frost forms in the pipes. Therefore, all distribution pipes should have drain valves at low points. Where freezing is expected, the lines should be oversized so that frost formation will not restrict the flow of gas to the silos.

Many alfalfa plants find it desirable to partially remove water vapor, using a refrigerated gas cooler. In a few installations, the dewpoint is further reduced by a dryer containing a desiccant, activated alumina, to -40° F., thus avoiding all possibility of frost in the lines and furnishing a very dry gas to the storage tanks.

Inert Gas Capacity

The volume of inert gas required for any installation varies greatly, depending on the tightness of the storage tanks or silos. Usually, for tight tanks, 200 to 350 cubic feet per hour per tank is required after the initial purging. A good rule of thumb is to allow a thousand cubic feet per hour of inert gas for each 2,500 tons of storage where the tanks are tightly sealed.

In most cases, although an installation starts with tight tanks, leakage increases over time. Tanks are subject to expansion and contraction both from temperature changes and from stresses due to the weight of the stored alfalfa. Wind also causes flexing of the tanks. When leakage increases, the vitamins and nutrients will be retained only by increasing the inert gas flow. Therefore, the inert gas generator should be large enough to have a considerable reserve capacity or a substantial loss of vitamins may result.

Since it is necessary to provide a continuous flow of gas across the silos to compensate for leakage losses and temperature changes, the gas generator should be dependable so that long periods of shutdown time are eliminated. Inert gas storage provides the most efficient and least costly method of long-term preservation of alfalfa and retention of the valuable carotene, vitamins E and K, xanthophyll, and other nutrients.

Operating Procedure

Inert gas is generated at approximately ½ pound pressure and may be piped directly to the storage tanks, which are usually under less than 1" water column pressure. As previously mentioned, distribution piping should be of ample size and should include drains at low points.

Prior to filling with alfalfa, the empty tank is purged with inert gas. To satisfactorily reduce the oxygen, there should be three to five volume changes

during the purging period. Purging is continued during filling and is reduced to a constant low level (bleed) after the tank is closed. It may be necessary to increase the flow while alfalfa is being withdrawn, particularly if this operation is extended.

Storage Tanks

New tanks erected for alfalfa storage will be gas-tight, and should have provisions for sealing the fill and withdrawal ports to reduce leakage as much as possible. Where old tanks are used special treatment is necessary to adequately seal the leaks and retain the inert gas, depending upon their construction. Each tank is equipped with a pressure relief valve which opens at 1"-2" water column pressure. When ambient temperature increases, pressure will build up in the tanks and must be relieved to prevent their bursting. When temperatures drop, the valves close and gas flow from the generator will increase and prevent collapse.

The importance of starting with tight tanks cannot be stressed too heavily, as this achieves the primary objective of excluding oxygen. In addition, when tanks are tight, smaller inert gas generating equipment can be installed and lower utility costs for fuel gas and power provide continued savings over the years.

Storage Costs

Investment

Approximately 60 percent of each model's output is assumed to be stored and storage facilities require a considerable investment. For models without separation, storage facilities and equipment would cost between $121,800 and $320,800 (table 17). Models that separate require more bins for segregation plus separate equipment for the pellets and cubes. Investments for these models would increase from $124,580 to $337,100 (table 17). Investment per ton of storage ranges from $42 to $33 for a plant with separate products and from $41 to $31 for plants without separation. Facilities account for 65 to 78 percent of total investment for all models. The facilities' share the total costs increases with the plant size. A detailed breakdown of equipment size and storage facilities required for each model is in appendix C.

Operating Costs

Storage of dehydrated alfalfa does create a significant added cost. Average storage cost per ton of stored product will range from $5.40 per ton for Model F without separated products to $7.69 for Model A with separation (table 18). Total costs for separation models range from 2 to 8 percent greater than storage costs for models not separating dehydrated alfalfa.

Table 17.--Storage facility and equipment costs for all models

Model and cost item	Without separation	With separation
	Dollars	
Model A:		
Facility	81,900	80,880
Equipment	39,900	43,700
Total	121,800	124,580
Model B:		
Facility	88,400	89,960
Equipment	40,400	44,200
Total	128,800	134,160
Model C:		
Facility	140,000	141,600
Equipment	47,800	53,900
Total	187,800	195,500
Model D:		
Facility	171,500	181,000
Equipment	54,700	62,700
Total	226,200	243,700
Model E:		
Facility	218,400	228,000
Equipment	65,400	74,800
Total	283,800	302,800
Model F:		
Facility	250,000	261,300
Equipment	70,800	75,800
Total	320,800	337,100

Table 18.--Storage operating costs, by model, with and without separation

Model and cost item	Without separation	With separation
	Dollars	
Model A:		
Fixed	4.91	5.04
Variable	2.58	2.65
Total	7.49	7.69
Model B:		
Fixed	4.43	4.61
Variable	2.30	2.41
Total	6.73	7.02
Model C:		
Fixed	4.04	4.22
Variable	2.07	2.16
Total	6.11	6.38
Model D:		
Fixed	3.80	4.11
Variable	1.95	2.12
Total	5.75	6.23
Model E:		
Fixed	3.72	3.95
Variable	1.88	2.03
Total	5.60	5.98
Model F:		
Fixed	3.57	3.75
Variable	1.83	1.94
Total	5.40	5.69

Total costs for both types decrease about 26 percent between Models A and F. Fixed costs for all models account for about 66 percent of total operating costs. Detailed costs for all models with and without separation are shown in tables 19 and 20.

Major items which contribute to operating expenses are maintenance, interest, and depreciation. Maintenance is high, due to a preventive program. As mentioned earlier, it is important that gas storage tanks and accessory equipment be airtight. This may be overstating such costs for new facilities, but with older tanks and equipment it may be slightly low.

Interest and depreciation are a function of investment; since added investment is high, so are these costs. Depreciation costs could be decreased if a longer period were used, but a 20-year period seems realistic for this industry.

Utilities make up a very small portion of the total storage cost: 17 to 24 cents per ton. Most of this cost stems from generating inert gas for maintenance of quality. These tables and detailed costs show that the cost of manufacturing inert gas for storage is not too great; rather, the storage facilities and equipment required prove expensive.

TOTAL OPERATING COSTS

Plant costs synthesized in the preceding sections have been combined for a review of total plant operating costs (table 21). Certain relationships were evident between the various size models. The total costs in table 21 will serve as a guide to dehydrators in assessing their particular cost situation. Other costs such as costs of acquiring, harvesting, trucking, and selling must be added to these synthesized costs for a total cost. These costs vary greatly with each geographic and market situation.

Total operating costs for separation models range from $26.22 a ton for alternative II, Model A, to $14.72 for Model F in alternative I. In the model operations without separation, total costs decline about 38 percent between Models A and F. Operating costs for the separation models drop about 40 percent between the smallest and the largest models.

Alternative II has the highest cost of the three separation flows. Separation models' costs range between 8 percent in Model F to 15 percent in Model A above the comparably sized model without separation. As models increase in size, there appear to be some economies of scale. As volume size increases the fixed-cost share of total cost decreases slightly.

Fixed costs for models without separation decrease from 39 to 34 percent between Models A and F. The three alternative separation models' fixed costs range from 42 percent in Model A to 36 percent in F.

The differences in total operating costs between the alternatives and the nonseparating model are also shown in table 21. The greatest differences occur in the smaller volume plants, but are reduced as volume increases. Alternative I is the least expensive separation flow of the three in the study. Increased costs range from 47 cents per ton for the larger Model F to $1.81 for Model A.

Table 19.--Storage cost for models without separation

Cost item	Model A		Model B		Model C		Model D		Model E		Model F	
	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton
	Dollars											
Fixed costs												
Administrative and salary (Supervisor)	500	0.17	500	0.14	600	0.11	600	0.09	700	0.08	700	0.07
Depreciation 1/	6,780	2.28	7,140	2.06	10,220	1.87	12,260	1.75	15,380	1.73	17,240	1.66
Insurance 2/	1,220	.41	1,290	.37	1,880	.34	2,270	.33	2,840	.32	3,210	.31
Taxes 3/	1,830	.62	1,940	.56	2,820	.52	3,400	.49	4,260	.48	4,810	.46
Interest 4/	4,270	1.43	4,510	1.30	6,580	1.20	7,920	1.14	9,943	1.11	11,230	1.07
Total	14,600	4.91	15,380	4.43	22,100	4.04	26,450	3.80	33,123	3.72	37,190	3.57
Variable costs												
Labor 5/	910	.31	910	.26	990	.18	1,070	.15	1,160	.13	1,250	.12
Utilities:												
Natural gas 6/	230	.08	230	.07	330	.06	410	.06	560	.06	640	.06
Electricity 7/	260	.09	260	.07	370	.07	470	.07	625	.07	730	.07
Water	160	.05	160	.05	230	.04	290	.04	390	.04	450	.04
Maintenance and repairs 8/	6,090	2.05	6,440	1.85	9,390	1.72	11,310	1.63	14,140	1.58	16,040	1.54
Total	7,650	2.58	8,000	2.30	11,310	2.07	13,550	1.95	16,875	1.88	19,110	1.83
Grand total	22,250	7.49	23,380	6.73	33,410	6.11	40,000	5.75	49,998	5.60	56,300	5.40

1/ Depreciation; straight line method: Equipment 15 years; bins and tanks, 20 years; building 25 years.
2/ Insurance: \$1 per \$100 initial investment.
3/ Taxes: 1½ percent initial investment.
4/ Interest: 7 percent on ½ average investment, 7 percent on land value.
5/ Labor: Average for mill labor \$2, maintenance labor \$2.30. (Includes 30 cents for fringe benefits.)
6/ Natural gas: 31 cents per 1,000 cubic feet.
7/ Electricity: 1.5 cents per kilowatt hour.
8/ Maintenance and repairs: 5 percent of initial investment.

Table 20.--Storage costs for models with separation

Cost item	Model A		Model B		Model C		Model D		Model E		Model F	
	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton
	Dollars											
Fixed costs												
Administrative and salary (Supervisor)	500	0.17	500	0.14	600	0.11	600	0.09	700	0.08	700	0.07
Depreciation 1/	6,990	2.35	7,470	2.15	10,690	1.96	13,250	1.90	16,400	1.84	18,130	1.74
Insurance 2/	1,250	.42	1,340	.39	1,960	.36	2,440	.35	3,030	.34	3,370	.32
Taxes 3/	1,870	.63	2,020	.58	2,940	.54	3,660	.53	4,550	.50	5,060	.49
Interest 4/	4,360	1.47	4,700	1.35	6,850	1.25	8,530	1.24	10,600	1.19	11,800	1.13
Total	14,970	5.04	16,030	4.61	23,040	4.22	28,480	4.11	35,280	3.95	39,060	3.75
Variable costs												
Labor 5/	960	.32	960	.28	1,050	.19	1,150	.17	1,260	.14	1,370	.13
Utilities:												
Natural gas 6/	230	.08	230	.07	340	.06	420	.06	570	.06	660	.06
Electricity 7/	320	.11	320	.09	460	.08	570	.08	770	.09	880	.08
Water	160	.05	160	.05	230	.04	290	.04	390	.04	450	.04
Maintenance and repairs 8/	6,220	2.09	6,710	1.92	9,780	1.79	12,190	1.77	15,140	1.70	16,860	1.63
Total	7,890	2.65	8,380	2.41	11,860	2.16	14,620	2.12	18,130	2.03	20,220	1.94
Grand total	22,860	7.69	24,410	7.02	34,900	6.38	43,100	6.23	53,410	5.98	59,280	5.69

1/ Depreciation; straight line method: Equipment 15 years; bins and tanks, 20 years; building 25 years.
2/ Insurance: $1 per $100 initial investment.
3/ Taxes: 1½ percent initial investment.
4/ Interest: 7 percent on ½ average investment, 7 percent on land value.
5/ Labor: Average for mill labor $2, maintenance labor $2.30. (Includes 30 cents for fringe benefits.)
6/ Natural gas: 31 cents per 1,000 cubic feet.
7/ Electricity: 1.5 cents per kilowatt hour.
8/ Maintenance and repairs: 5 percent of initial investment.

Table 21.--Average operating costs per ton for all models: Total, fixed, and variable cost 1/

Model and cost item	Method of operation: No separation	Separation		
	Standard	Alternative I	Alternative II	Alternative III
	Dollars			
Model A:				
Fixed	8.96	10.61	10.94	10.94
Variable	13.91	14.07	15.28	14.77
Total	22.87	24.68	26.22	25.71
Difference	--	1.81	3.35	2.84
Model B:				
Fixed	8.15	9.62	9.91	9.90
Variable	12.99	13.07	14.08	13.64
Total	21.14	22.69	23.99	23.54
Difference	--	1.55	2.85	2.40
Model C:				
Fixed	6.37	7.35	7.56	7.53
Variable	11.18	11.29	12.07	11.71
Total	17.55	18.64	19.63	19.24
Difference	--	1.09	2.08	1.69
Model D:				
Fixed	5.61	6.46	6.63	6.60
Variable	10.46	10.62	11.33	11.00
Total	16.07	17.08	17.96	17.60
Difference	--	1.01	1.89	1.53
Model E:				
Fixed	5.09	5.77	5.90	5.89
Variable	9.85	9.89	10.44	10.20
Total	14.94	15.66	16.34	16.09
Difference	--	.72	1.40	1.15
Model F:				
Fixed	4.89	5.45	5.58	5.55
Variable	9.36	9.27	9.87	9.58
Total	14.25	14.72	15.45	15.13
Difference	--	.47	1.20	.88

1/ Model costs include dehydration and storage costs for models not separating. Models separating dehydrated alfalfa include dehydration, separation, and storage costs.

Alternative II is the most expensive separation flow, with costs between $1.20 a ton for Model F to $3.35 for Model A. Alternative III has costs which are close to the average cost of I and II.

Average operating costs for each model has been allocated to the total plant output. This, in effect, overstates the actual plant costs for the 40 percent of dehydrated alfalfa production which may not be stored. On the other hand, it understates the estimated cost for the portion of production which is stored.

If separation becomes a commercial process, dehydrators must assign a portion of the separation costs to each of the two fractions. Each fraction should bear its share of the production cost. This will be reflected in the prices of both alfalfa fractions, but should make each more competitive with other ingredients. One method which may be used is to prorate costs over nutritional benefits of each fraction.

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APPENDIX A. BASIC EQUIPMENT IN THE MODELS

In tables 22-27, the equipment listed is assumed to be required for each of the six standard model plants. Equipment has been sized to the capacity of the dehydrating drum. In table 1, each model employs a different size drum. Drums are rated on the evaporative capacity per hour.

"The models," as used in the study, refers to each model's output as tons of dried alfalfa produced per hour of operation. Table 1 provides the comparison of rated capacity in terms of water removed to the tons of dried alfalfa. This relationship will vary with the moisture content of alfalfa, the season (wet or dry), time of day, and other factors.

Determining the optimum output from a particular size drum is a relatively simple calculation. The following formula may be used:

$$F = \frac{E\ (1-M_1)}{(M_1 - M_2)}\ (2{,}000)$$

In this equation, F is tons of product finished in 1 hour, E is evaporative capacity of the drum in 1 hour, M_1 is the moisture of the green alfalfa chop, and M_2 is moisture content of the dehydrated product. To illustrate: assuming that the alfalfa chop has 80 percent moisture, the dehydrated product would have 8 percent moisture. What would be the maximum hourly output of a drum with evaporative capacity of 12,000 pounds per hour?

$$F = \frac{12{,}000\ (1 - .75)}{(.75 - .08)\ (2{,}000)}$$

$$= \frac{(12{,}000)\ (.25)}{(.67)\ (2{,}000)}$$

$$= \frac{3{,}000}{1{,}340}$$

$$= 2.2 \text{ tons per hour}$$

Because it is unlikely that plants will operate at 100-percent capacity, the output of drums in models was set at 75 to 80 percent capacity.

Basic equipment for the standard models is briefly described in the following tables. Equipment is grouped according to the basic operations: receiving, dehydrating, grinding, pelleting, and loading out. As separation equipment is added to the basic process, a rearrangement is required to satisfy the varying requirements of each model.

For example, pelleting equipment would be sufficient to handle the pelleting needs of the standard models. With separation included, additional pelleting equipment would be required to handle the two lines of products. The equipment listed in the tables has sufficient capacity to handle the total output of the models, regardless of change in operations.

Table 22.--Basic equipment for alfalfa dehydrating model productng 1 1/2 tons per hour

Plant equipment	Size or capacity	Motor
		Horsepower
Receiving:		
Truck platform, hydraulic dump....	11' x 24'	5
Automatic forage feeder...........	10' x 20'	2-2
Dehydrating:		
Conveyor, screw..................	16" x 21'	5
Rotary drum, single-pass..........	9-10,000 lb. water per hr.	20
Pneumatic system, positive........	3 tons per hr.	60
Grinding:		
Hammermill........................	20" negative	100
Pneumatic system, negative with airlock........................	3 tons per hr.	1-25, 1-3/4
Pelleting:		
Screw feeder, twin live bottom....	9" x 10'	5
Pellet mill, single-speed.........	3 tons per hr.	75
Elevator, stainless-steel bucket..	4" x 20'	1
Cooler, vertical..................	3 tons per hr.	10
Scalper...........................	60" x 72"	1/2
Automatic scale...................	3 tons per hr.	1
Pneumatic system, positive........	7,000 lb. per hr., 6" line	20
Boiler............................	20 hp., high-pressure	--
Loading out:		
Conveyor, screw-tube type 1/......	9" x 18'	3

1/ 2 units.

Table 23.--Basic equipment for alfalfa dehydrating model producing 1 3/4 tons per hour

Plant equipment	Size or capacity	Motor
		Horsepower
Receiving:		
Truck platform, hydraulic dump....	11' x 24'	5
Automatic forage feeder..........	10' x 20'	1-2, 1-5
Dehydrating:		
Conveyor, drag....................	16" x 16'5"	3
Rotary drum, triple-pass..........	12,000 lb. water per hr.	20
Pneumatic system, positive........	3 tons per hr.	75
Grinding:		
Hammermill........................	20' negative	100
Pneumatic system, negative with airlock........................	3 tons per hr.	1-25, 1-3/4
Pelleting:		
Screw feeder, twin live bottom....	9" x 10'	5
Pellet mill, single-speed.........	3 tons per hr.	75
Elevator, stainless-steel bucket..	4" x 20'	1
Cooler, vertical..................	3 tons per hr.	10
Scalper...........................	60" x 72"	1/2
Automatic scale...................	3 tons per hr.	1
Pneumatic system, positive........	7,000 lb. per hr., 6" line	20
Boiler............................	20 hp., high-pressure	--
Loading out:		
Conveyor, screw-tube type 1/......	9" x 18'	3

1/ 2 units.

Table 24.--Basic equipment for alfalfa dehydrating model producing 2 3/4 tons per hour

Plant equipment	Size or capacity	Motor
		Horsepower
Receiving:		
Truck platform, hydraulic dump....	11' x 28'	7 1/2
Automatic forage feeder	10' x 20'	2-2
Dehydrating:		
Conveyor, screw..................	16" x 21'	5
Rotary drum, single-pass..........	18,000 lb. water per hr.	20
Pneumatic system, positive........	5 tons per hr.	60
Grinding:		
Hammermill.......................	30" negative	125
Pneumatic system, negative with airlock.......................	5 tons per hr.	1-25, 1-3/4
Pelleting:		
Screw feeder, twin live bottom....	9" x 20'	5
Pellet mill, single-speed.........	5 tons per hr.	100
Elevator, stainless-steel bucket..	4" x 20'	1
Cooler, vertical..................	5 tons per hr.	15
Scalper..........................	60" x 72"	1/2
Automatic scale..................	5 tons per hr.	1
Pneumatic system, positive........	12,000 lb. per hr., 6" line	25
Boiler...........................	40 hp., high-pressure	--
Loading out:		
Conveyor, screw-tube type 1/......	9" x 18'	3

1/ 3 units.

Table 25.--Basic equipment for alfalfa dehydrating model producting 3 1/2 tons per hour

Plant equipment	Size or capacity	Motor
		Horsepower
Receiving:		
Truck platform, hydraulic dump	11' x 28'	7 1/2
Automatic forage feeder	10' x 24'	1-2, 1-5
Dehydrating:		
Conveyor, drag	16" x 16' 5"	3
Rotary drum, triple-pass	22,000 lb. water per hr.	20
Pneumatic system, positive	5 tons per hr.	100
Grinding:		
Hammermill	30" negative	150
Pneumatic system, negative with airlock	5 tons per hr.	1-25, 1-3/4
Pelleting:		
Screw feeder, twin live bottom	9" x 20'	5
Pellet mill, single-speed	5 tons per hr.	100
Elevator, stainless-steel bucket	4" x 25'	1
Cooler, vertical	5 tons per hr.	15
Scalper	60" x 72"	1/2
Automatic scale	5 tons per hr.	1
Pneumatic system, positive	12,000 lb. per hr., 6" line	25
Boiler	40 hp., high-pressure	--
Loading out:		
Conveyor, screw-tube type 1/	9" x 18'	3

1/ 3 units.

Table 26.--Basic equipment for alfalfa dehydrating model producing 4 1/2 tons per hour

Plant equipment	Size or capacity	Motor
		Horsepower
Receiving:		
Truck platform, hydraulic dump....	11' x 28'	7 1/2
Automatic forage feeder..........	10' x 20'	2-2
Dehydrating:		
Conveyor, screw..................	16" x 22'	5
Rotary drum, single-pass..........	30,000 lb. water per hr.	25
Pneumatic system, positive........	7 tons per hr.	150
Grinding:		
Hammermill........................	30" negative	150
Pneumatic system, negative with airlock........................	7 tons per hr.	1-25, 1-3/4
Pelleting:		
Screw feeder, twin live botom.....	9" x 20'	5
Pellet mill, single-speed.........	7 tons per hr.	150
Elevator, stainless-steel bucket..	4" x 30'	1
Cooler, vertical..................	7 tons per hr.	
Scalper...........................	60" x 72"	1
Automatic scale...................	7 tons per hr.	1
Pneumatic system, positive........	18,000 lb. per hr., 8" line	30
Boiler............................	50 hp., high-pressure	--
Loading out:		
Conveyor, screw-tube type 1/......	9" x 18'	3

1/ 4 units.

Table 27.--Basic equipment for alfalfa dehydrating model producting 5 1/4 tons per hour

Plant equipment	Size or capacity	Motor
		Horsepower
Receiving:		
Truck platform, hydraulic dump....	11' x 28'	7 1/2
Automatic forage feeder...........	10' x 20'	1-3, 1-5
Dehydrating:		
Conveyor, drag....................	24" x 18'	3
Rotary drum, triple-pass..........	33-34,000 lb. water per hr.	25
Pneumatic system, positive........	7 tons per hr.	150
Grinding:		
Hammermill........................	30" negative	200
Pneumatic system, negative with airlock........................	7 tons per hr.	1-25, 1-3/4
Pelleting:		
Screw feeder, twin live bottom....	9" x 20'	5
Pellet mill, single-speed.........	7 tons per hr.	150
Elevator, stainless-steel bucket..	4" x 30'	1
Cooler, vertical..................	7 tons per hr.	20
Scalper...........................	60" x 72"	1
Automatic scale...................	7 tons per hr.	1
Pneumatic system, positive........	18,000 lb. per hr., 8" line	30
Boiler............................	50 hp., high-pressure	--
Loading out:		
Conveyor, screw-tube type 1/......	9" x 18'	3

1/ 4 units.

Table 28.--Separation Alternative I, depreciation costs: All models

Item	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Equipment:						
Total cost	184,500	200,350	206,600	226,100	243,400	284,200
Annual depreciation	12,300	13,360	13,780	15,080	16,230	18,950
Depreciation per ton	2.48	2.31	1.52	1.31	1.09	1.09
Mill building and boilerroom:						
Total cost	19,700	19,700	25,700	25,700	29,500	29,500
Annual depreciation	790	790	1,030	1,030	1,180	1,180
Depreciation per ton	.16	.13	.11	.09	.08	.07
Office and shop:						
Total cost	9,600	9,600	14,500	14,500	18,900	18,900
Annual depreciation	390	390	580	580	760	760
Depreciation per ton	.08	.07	.06	.05	.05	.04
Loading out tanks:						
Total cost	32,400	32,400	43,800	43,800	45,200	45,200
Annual depreciation	1,620	1,620	2,190	2,190	2,260	2,260
Depreciation per ton	.33	.28	.24	.19	.15	.13
Total:						
Total cost	246,200	262,050	290,600	310,100	337,000	377,800
Annual depreciation	15,100	16,160	17,580	18,880	20,430	23,150
Depreciation per ton	3.05	2.79	1.93	1.64	1.37	1.33

Table 29.--Separation Alternative II, depreciation costs: All models

Item	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Equipment:						
Total cost	197,250	213,100	221,600	241,100	259,100	301,300
Annual depreciation	13,150	14,210	14,780	16,080	17,280	20,090
Depreciation per ton	2.65	2.46	1.63	1.39	1.16	1.16
Mill building and boilerroom:						
Total cost	19,700	19,700	25,700	25,700	29,500	29,500
Annual depreciation	790	790	1,030	1,030	1,180	1,180
Depreciation per ton	.16	.13	.11	.09	.08	.07
Office and shop:						
Total cost	9,600	9,600	14,500	14,500	18,900	18,900
Annual depreciation	390	390	580	580	760	760
Depreciation per ton	.08	.07	.06	.05	.05	.04
Loading out tanks:						
Total cost	32,400	32,400	43,800	43,800	45,200	45,200
Annual depreciation	1,620	1,620	2,190	2,190	2,260	2,260
Depreciation per ton	.33	.28	.24	.19	.15	.13
Total:						
Total cost	258,950	274,800	305,600	325,100	352,700	394,900
Annual depreciation	15,950	17,010	18,580	19,880	21,480	24,290
Depreciation per ton	3.22	2.94	2.04	1.72	1.44	1.40

Table 30.--Separation Alternative III, depreciation costs: All models

Item	Model A	Model B	Model C	Model D	Model E	Model F
	Dollars					
Equipment:						
Total cost	197,250	213,100	219,350	238,850	258,350	298,000
Annual depreciation	13,150	14,210	14,630	15,930	17,230	19,870
Depreciation per ton	2.65	2.46	1.62	1.38	1.16	1.15
Mill building and boilerroom:						
Total cost	19,700	19,700	25,700	25,700	29,500	29,500
Annual depreciation	790	790	1,030	1,030	1,180	1,180
Depreciation per ton	.16	.13	.11	1.09	.08	.07
Office and shop:						
Total cost	9,600	9,600	14,500	14,500	18,900	18,900
Annual depreciation	390	390	580	580	760	760
Depreciation per ton	.08	.07	.06	.05	.05	.04
Loading out tanks:						
Total cost	32,400	32,400	43,800	43,800	45,200	45,200
Annual depreciation	1,620	1,620	2,190	2,190	2,260	2,260
Depreciation per ton	.33	.28	.24	.19	.15	.13
Total:						
Total cost	258,950	274,800	303,850	322,850	351,950	391,600
Annual depreciation	15,950	17,010	18,430	19,730	21,430	24,070
Depreciation per ton	3.22	2.94	2.03	1.71	1.44	1.39

APPENDIX C. STORAGE EQUIPMENT AND FACILITIES

Storage presents a major question to many alfalfa dehydrators. All agree storage is a necessary and significant part of marketing. The question then arises, "Should storage be at the plant or should several dehydrators build a large, central storage facility?" This question is difficult to answer.

The individual situation will most frequently dictate which direction management must go. Some regulate storage according to market prices. Others store about half their output to allow marketing at a more opportune time. Still others store early season production for several months and move it out as they need more space.

With separation, storage of the high-protein fraction must preserve the quality of this higher valued product. Stocks of this product must be maintained throughout the year to guarantee a steady supply to feed manufacturers.

Tables 31 through 42 present the basic detailed information on storage tanks and equipment needed for each of the models. Tables 31 to 36 have the cost data for plants without separated products. Tables 37 through 42 show costs for separated products. The major differences are (1) more storage facilities and (2) separate handling systems for each product with flexibility for blending. These differences result in increased operating costs (tables 18, 19, and 20).

Table 31.--Storage equipment and facility costs for model A 1/

Item	Number	Capacity	Cost 2/	Depreciation Total	Depreciation Per ton
			- - - - -	Dollars	- - - - -
Storage tanks	3	3,150 tons 31' x 64'	81,900	4,100	1.38
Generator, inert gas	1	2,000 cu. ft./hr.	5,200	350	.12
Refrigeration unit	1	2,500 cu. ft./hr.	3,200	220	.07
Conveyor, screw	1	9" x 110'	7,400	500	.17
Conveyors, screw	3	12" x 25'	7,600	510	.17
Conveyor, belt	1	24" x 100'	9,900	660	.22
Elevator, bucket	1	12" x 60'	6,600	440	.15
Total			121,800	6,780	2.28

1/ For models without separation.
2/ Includes installation.

Table 32.--Storage equipment and facility costs for model B 1/

Item	Number	Capacity	Cost 2/	Depreciation Total	Depreciation Per ton
			- - - - -	Dollars	- - - - -
Storage tanks	3	3,450 tons 38' x 48'	88,400	4,420	1.28
Generator, inert gas	1	2,000 cu. ft./hr.	5,200	350	.10
Refrigeration unit	1	2,500 cu. ft./hr.	3,200	220	.06
Conveyor, screw	1	9" x 110'	7,400	500	.14
Conveyors, screw	3	12" x 25'	7,600	510	.15
Conveyor, belt	1	24" x 110'	10,400	700	.20
Elevator, bucket	1	12" x 60'	6,600	440	.13
Total			128,800	7,140	2.06

1/ For models without separation.
2/ Includes installation.

Table 33.--Storage equipment and facility costs for model C 1/

Item	Number	Capacity	Cost 2/	Depreciation	
				Total	Per ton
			----- Dollars -----		
Storage tanks	4	5,600 tons 38' x 58'	140,000	7,000	1.28
Generator, inert gas	1	3,000 cu. ft./hr.	6,200	420	.08
Refrigeration unit	1	3,000 cu. ft./hr.	3,500	240	.04
Conveyors, screw	2	9" x 72'	9,200	620	.11
Conveyors, screw	4	12" x 35'	12,800	860	.16
Conveyor, belt	1	24" x 85'	9,500	640	.12
Elevator, bucket	1	12" x 60'	6,600	440	.08
Total			187,800	10,220	1.87

1/ For models without separation.
2/ Includes installation

Table 34.--Storage equipment and facility costs for model D 1/

Item	Number	Capacity	Cost 2/	Depreciation	
				Total	Per ton
			----- Dollars -----		
Storage tanks	5	7,000 tons 38' x 58'	171,500	8,580	1.24
Generator, inert gas	1	3,000 cu. ft./hr.	6,200	420	.06
Refrigeration unit	1	3,000 cu. ft./hr.	3,500	240	.03
Conveyors, screw	1	9" x 72'	4,600	310	.04
	1	9" x 110'	7,400	500	.07
Conveyors, screw	5	12" x 35'	16,000	1,070	.15
Conveyor, belt	1	24" x 110'	10,400	700	.10
Elevator, bucket	1	12" x 60'	6,600	440	.06
Total			226,200	12,260	1.75

1/ For models without separation.
2/ Includes installation.

Table 35.--Storage equipment and facility costs for model E 1/

Item	Number	Capacity	Cost 2/	Depreciation Total	Depreciation Per ton
			- - - - -	Dollars	- - - - -
Storage tanks	6	9,000 tons 38' x 64'	218,400	11,000	1.24
Generator, inert gas	1	4,000 cu. ft./hr.	7,500	500	.06
Refrigeration unit	1	4,000 cu. ft./hr.	3,800	260	.03
Conveyors, screw	1	9" x 110'	7,400	500	.06
	1	9" x 150'	9,600	640	.07
Conveyors, screw	6	12" x 35'	19,200	1,280	.14
Conveyor, belt	1	24" x 150'	11,300	760	.08
Elevator, bucket	1	12" x 60'	6,600	440	.05
Total			283,800	15,380	1.73

1/ For models without separation.
2/ Includes installation.

Table 36.--Storage equipment and facility costs for model F 1/

Item	Number	Capacity	Cost 2/	Depreciation Total	Depreciation Per ton
			- - - - -	Dollars	- - - - -
Storage tanks	7	10,600 tons 38' x 64'	250,000	12,500	1.21
Generator, inert gas	1	4,000 cu. ft./hr.	7,500	500	.05
Refrigeration unit	1	4,000 cu. ft./hr.	3,800	260	.02
Conveyors, screw	2	9" x 150'	19,200	1,280	.12
Conveyors, screw	7	12" x 35'	22,400	1,500	.15
Conveyor, belt	1	24" x 150'	11,300	760	.07
Elevator, bucket	1	12" x 60'	6,600	440	.04
Total			320,800	17,240	1.66

1/ For models without separation.
2/ Includes installation.

Table 37.--Storage equipment and facility costs for model A 1/

Item	Number	Capacity	Cost 2/	Depreciation	
				Total	Per ton
			- - - - - Dollars - - - - -		
Storage tanks.........	3	1,560 tons 25' x 53'	40,560	4,050	1.36
Storage, flat steel...	1	1,600 tons 60' x 84'	40,320		
Generator, inert gas..	1	2,000 cu. ft./hr.	5,200	350	.12
Refrigeration unit....	1	2,500 cu. ft./hr.	3,200	220	.07
Conveyors, screw......	3	14" x 21'	6,100	410	.14
Conveyors, screw......	2	9" x 72'	8,800	590	.20
Conveyor, belt........	1	24" x 75'	6,100	410	.14
Conveyor, belt........	1	24" x 84'	6,800	460	.15
Elevator, bucket......	1	18" x 60'	7,500	500	.17
Total..............			124,580	6,990	2.35

1/ For models with separation.
2/ Includes installation.

Table 38.--Storage equipment and facility costs for model B 1/

Item	Number	Capacity	Cost 2/	Depreciation	
				Total	Per ton
			- - - - - Dollars - - - - -		
Storage tanks.........	3	1,750 tons 25' x 59'	46,260	4,500	1.30
Storage, flat steel...	1	1,750 tons 60' x 90'	43,700		
Generator, inert gas..	1	2,000 cu. ft./hr.	5,200	350	.10
Refrigeration unit....	1	2,500 cu. ft./hr.	3,200	220	.06
Conveyors, screw......	3	14" x 21'	6,100	410	.12
Conveyors, screw......	2	9" x 72'	8,800	590	.17
Conveyor, belt........	1	24" x 75'	6,100	410	.12
Conveyor, belt........	1	24" x 90'	7,300	490	.14
Elevator, bucket......	1	18" x 60'	7,500	500	.14
Total..............			134,160	7,470	2.15

1/ For models with separation.
2/ Includes installation.

Table 39.--Storage equipment and facility cost for model C 1/

Item	Number	Capacity	Cost 2/	Depreciation	
				Total	Per ton
			- - - - - -	Dollars	- - - - -
Storage tanks.........	4	2,750 tons 31' x 44'	72,400		
				7,080	1.30
Storage, flat steel...	1	2,740 tons 81' x 108'	69,200		
Generator, inert gas..	1	3,000 cu. ft./hr.	6,200	420	.08
Refrigeration unit....	1	3,000 cu. ft./hr.	3,500	240	.04
Conveyors, screw......	4	14" x 21'	9,000	600	.11
Conveyors, screw......	2	9" x 100'	12,000	800	.15
Conveyor, belt........	1	24" x 75'	6,100	410	.07
Conveyor, belt........	1	24" x 120'	9,600	640	.12
Elevator, bucket......	1	18" x 60'	7,500	500	.09
Total...............			195,500	10,690	1.96

1/ For models with separation.
2/ Includes installation.

Table 40.--Storage equipment and facility costs for model D 1/

Item	Number	Capacity	Cost 2/	Depreciation	
				Total	Per ton
			- - - - - -	Dollars	- - - - -
Storage tanks.........	6	3,500 tons 25' x 58'	90,000		
				9,050	1.30
Storage, flat steel...	2	3,600 tons 60' x 96'	91,000		
Generator, inert gas..	1	3,000 cu. ft./hr.	6,200	420	.06
Refrigeration unit....	1	3,000 cu. ft./hr.	3,500	240	.03
Conveyors, screw......	6	14" x 21'	12,000	800	.12
Conveyors, screw......	2	9" x 75'	9,000	600	.09
Conveyor, belt........	1	24" x 80'	6,500	440	.06
Conveyor, belt........	2	24" x 100'	18,000	1,200	.17
Elevator, bucket......	1	18" x 60'	7,500	500	.07
Total...............			243,700	13,250	1.90

1/ For models with separation.
2/ Includes installation.

Table 41.--Storage equipment and facility costs for model E 1/

Item	Number	Capacity	Cost 2/	Depreciation Total	Depreciation Per ton
			Dollars		
Storage tanks..........	5	4,400 tons	111,500		
		31' x 58'		11,400	1.28
Storage, flat steel....	2	4,500 tons	116,500		
		80' x 90'			
Generator, inert gas...	1	4,000 cu. ft./hr.	7,500	500	.06
Refrigeration unit.....	1	4,000 cu. ft./hr.	3,800	260	.03
Conveyors, screw.......	5	14" x 25'	11,000	740	.08
Conveyors, screw.......	2	9" x 90'	18,000	1,200	.13
		9" x 60'			
Conveyor, belt.........	1	24" x 100'	9,000	600	.07
Conveyor, belt.........	2	24" x 100'	18,000	1,200	.13
Elevator, bucket.......	1	18" x 60'	7,500	500	.06
Total................			302,800	16,400	1.84

1/ For models with separation.
2/ Includes installation.

Table 42.--Storage equipment and facility costs for model F 1/

Item	Number	Capacity	Cost 2/	Depreciation Total	Depreciation Per ton
			Dollars		
Storage tanks..........	5	5,300 tons	130,500		
		31' x 64'		13,060	1.25
Storage, flat steel....	2	5,300 tons	130,800		
		80' x 104'			
Generator, inert gas...	1	4,000 cu. ft./hr.	7,500	500	.05
Refrigeration unit.....	1	4,000 cu. ft./hr.	3,800	260	.02
Conveyors, screw.......	5	14" x 25'	11,000	740	.07
Conveyors, screw.......	2	9" x 90'	18,000	1,200	.12
		9" x 60'			
Conveyor, belt.........	1	24" x 100'	9,000	600	.06
Conveyor, belt.........	2	24" x 110'	19,000	1,270	.12
Elevator, bucket.......	1	18" x 60'	7,500	500	.05
Total................			337,100	18,130	1.74

1/ For models with separation.
2/ Includes installation.

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